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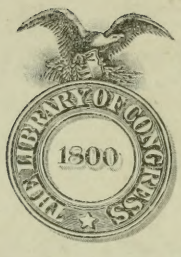


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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 640

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ April 8, 1918

# THE MEDITERRANEAN FRUIT FLY

By

E. A. BACK, Entomologist, and C. E. PEMBERTON, Assistant Entomologist, Mediterranean and Other Fruit Fly Investigations

## CONTENTS

| | Page |
|---|---|
| Distribution Throughout the World | 2 |
| Establishment and Spread in Hawaii | 3 |
| How the Fruit Fly got into Hawaii | 4 |
| Losses Incurred Through the Fruit Fly | 5 |
| What the Mediterranean Fruit Fly is Like | 7 |
| Fruits, Nuts, and Vegetables Attacked | 11 |
| Host Fruits of Commercial Value | 15 |
| Artificial Methods of Control not Satisfactory Under Hawaiian Conditions | 24 |
| The Campaign Against the Fruit Fly in Hawaii | 26 |
| Natural Control of the Fruit Fly | 37 |
| Quarantine Measures to Prevent Introduction | 41 |
| Summary | 42 |

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1918

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ONE OF THE WORST enemies of fruit grown in tropical and semitropical countries is the Mediterranean fruit fly. Constant vigilance is necessary to prevent its establishment in North America. It is particularly destructive because it is difficult to control and attacks many kinds of fruits, nuts, and vegetables. In the Hawaiian Islands, where it has caused great damage since 1910, it attacks 72 kinds of fruits. A partial list of these contains oranges, grapefruit, lemons, limes, kumquats, tangerines, peaches, apples, figs, apricots, bananas, mangoes, avocados, sapotas, loquats, persimmons, guavas, quinces, papayas, pears, plums, grapes, eggplant, tomatoes, and even cotton bolls. Most of these are now grown or can be grown in our Southern States, the Gulf region, and California and the Southwest.

The purpose of this bulletin is to give alike to the citizen of Hawaii, the fruit grower of the United States mainland, and the traveler information that will help to convey a clear conception of the difficult problem that has developed with the introduction of the Mediterranean fruit fly into the Hawaiian Islands. The pest can be kept out of the rich semitropical fruit-growing sections of the United States only by the hearty and intelligent cooperation of all.

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CONTENTS.

| | Page. | | Page. |
|---|---|---|---|
| Distribution throughout the world | 2 | Artificial methods of control not satisfactory under Hawaiian conditions | 24 |
| Establishment and spread in Hawaii | 3 | The campaign against the fruit fly in Hawaii | 26 |
| How the fruit fly got into Hawaii | 4 | Natural control of the fruit fly | 37 |
| Losses incurred through the fruit fly | 5 | Quarentine measures to prevent introduction | 41 |
| What the Mediterranean fruit fly is like | 7 | Summary | 42 |
| Fruits, nuts, and vegetables attacked | 11 | | |
| Host fruits of commercial value | 15 | | |

THE HORTICULTURAL DEVELOPMENT of the Hawaiian Islands has been almost stopped since 1910 by the activity of two fruit-fly pests—the Mediterranean fruit fly[1] and the melon fly.[2 3]

These two pests are being intercepted continually by quarantine officials at our ports of entry and they are therefore feared by, and are of vital interest to, every fruit and vegetable grower in the warmer portions of the Pacific and Gulf coast States. Every possible barrier to the establishment of these pests on the mainland United States is being erected by the Federal Horticultural Board, working in cooperation with State officials. Quarantines now regulate the movement of horticultural products from infested countries; hence the greatest danger to California, Florida, and Mexican territory now lies in the unintentional spread of fruit-fly pests by uninformed travelers who may carry infested fruits upon their persons or in their baggage.

The Mediterranean fruit fly (fig. 1) is one of the recently introduced pests of Hawaii. It has found climatic and food conditions so favorable that at present there is not a family unaffected by its ravages. It is doubtful if there exist in any other place in the world conditions so favorable to the rapid spread and thorough establishment of this pest as those in the Hawaiian Islands.

[1] "The Mediterranean Fruit Fly in Hawaii," E. A. Back and C. E. Pemberton, Department of Agriculture Bulletin 536. (*Ceratitis capitata* Wied.)

[2] "The Melon Fly in Hawaii," E. A. Back and C. E. Pemberton, Department of Agriculture Bulletin 491. (*Bactrocera cucurbitae* Coq.)

[3] "The Melon Fly," E. A. Back, C. E. Pemberton, Department of Agriculture Bulletin 643.

NOTE.—The manuscript of this paper was prepared for publication as a Farmers' Bulletin, but owing to the fact that it deals with an insect which has not yet been introduced into the United States it was considered more appropriate to issue it in the series of Department Bulletins.

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## DISTRIBUTION THROUGHOUT THE WORLD.

The Mediterranean fruit fly is a cosmopolitan pest. It has been known to science for 100 years and during these years has spread throughout the world, until to-day the North American continent is the only large land area upon which it has not become established. It first attracted serious attention in London, where oranges arriving from the Azores were discovered to be badly decayed and wormy. (See fig. 2.) It was recorded as a pest in Spain in 1842, in Algeria in 1858, in Italy in 1863, in Sicily in 1878, and in Tunis in 1885. In 1889 it was first reported in South Africa. It became established in the western part of Australia in 1897 and in the eastern part in

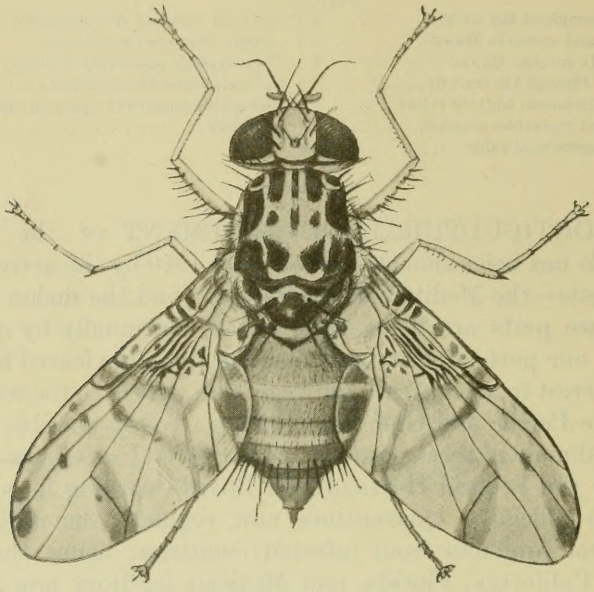


FIG. 1.—Adult male Mediterranean fruit fly. Greatly enlarged. (Howard.)

1898. In 1899 it was detected in Tasmania, in 1900 it was found attacking the apricot orchards near Paris, France, and during 1901 it was reported from New Zealand and Brazil. Compere, in 1904, found the pest in Egypt, and in Asiatic Turkey at Beirut and Jerusalem. Argentina was reported infested in 1905. Between 1909 and 1914 it was found in the eastern and western parts of Africa, and in 1915 it was first reported from the Island of Madagascar. During 1916 it caused serious damage to the orange, tangerine, peach, pear, and apple crops of the Patras consular district of Greece. It is claimed that this was the first time in 10 years or more that this pest had been noticed in this district of Greece. The Bermuda Islands became infested during 1865.

## ESTABLISHMENT AND SPREAD IN HAWAII.

The presence of the Mediterranean fruit fly in the Hawaiian Islands was first discovered at Honolulu on June 21, 1910, and by the fall of that year the pest was well established in the Punchbowl district of the city. By October, 1911, it was found on the Island of Kauai, and by January, 1912, on the Island of Molokai and in the Kohala district of the Island of Hawaii (see fig. 3). During March, 1912,

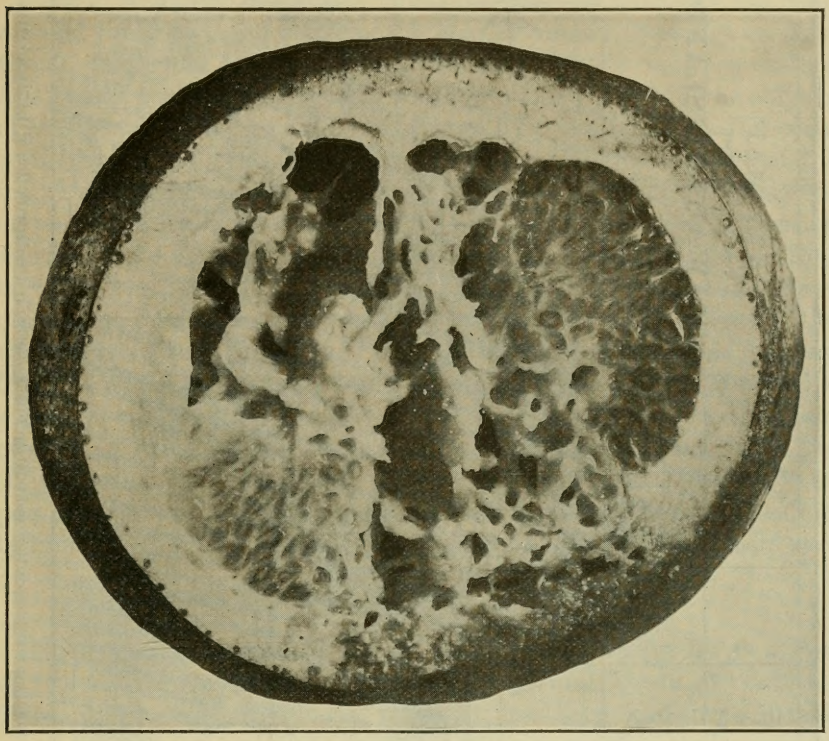
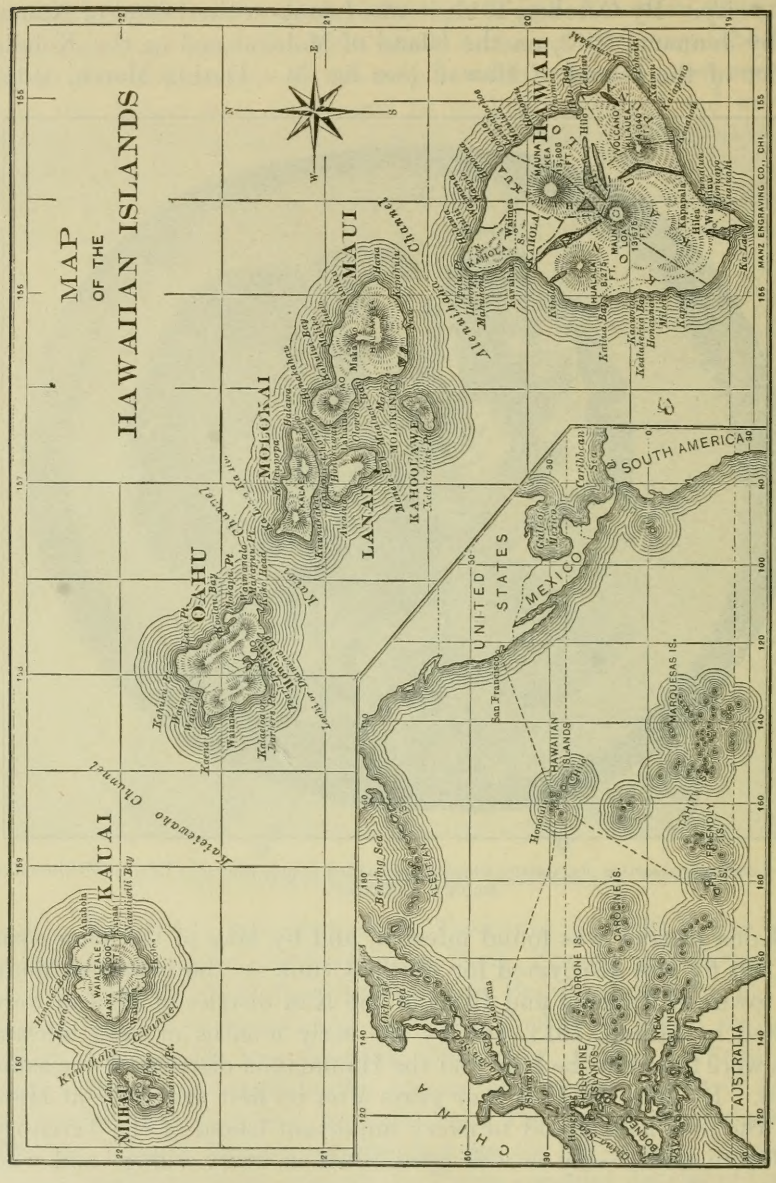


FIG. 2.—Longitudinal section of grapefruit showing destruction of pulp caused by larvæ of Mediterranean fruit fly. (Original.)

the Kona district was found infested, and by May of the same year the fruit fly was discovered for the first time on the Island of Maui. The towns of Naalehu and Hilea of the Kau district of Hawaii were infested by March, 1913, and by the early months of 1914 infestations were found in the Hilo and the Hammakua districts of the same island. By July, 1914, or four years after its first discovery at Honolulu, the pest had spread to every important island of the Territory of Hawaii and to-day is well established in every village and wild guava scrub.

## HOW THE FRUIT FLY GOT INTO HAWAII.

A number of popular accounts tell how the Mediterranean fruit fly became established in Honolulu, but they are without foundation.


MAP
OF THE
HAWAIIAN ISLANDS
HAWAII
MAUI
KAHOOLAWE
LANAI
MOLOKAI
OAHU
KAUAI
NIIHAU
SOUTH AMERICA
UNITED STATES
MEXICO
AUSTRALIA
NEW GUINEA
PHILIPPINE ISLANDS
CAROLINE IS.
MARQUESAS IS.
FIJI IS.
HAWAIIAN ISLANDS
San Francisco
Honolulu
Yokohama
Shanghai
Manila
Sydney
Auckland
Tahiti
Guam
Samoa
Tonga
Gilbert Is.
Marshall Is.
Solomon Is.
Bismarck Archipelago
Caroline Is.
Kaiulani
Mauna Loa
Hualalai
Haleakala
Waialeale
Kilauea
Mauna Kea
Kohala
Hilo
Kona
Kau
Puna
Hamakua
Kamuela
Waimea
Kawaihae
Lahaina
Wailuku
Kahului
Makawao
Honolua
Honokaa
Kaanapali
Kihau
Waimea
Hanapepe
Koloa
Lihue
Kapaa
Hanalei
Waialua
Honolulu
Pearl Harbor
Ewa
Waianae
Kaneohe
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Waimea
Kekaha
Makaweli
Hanapepe
Koloa
Lihue
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Hanalei
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Waimea
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Makaweli
Kawaihae
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Hilo
Kona
Kau
Puna
Hamakua
Kamuela
Waimea

at Honolulu plied between countries not infested by this pest. Eastern Australia was not infested before 1898. With the development of rapid ocean transportation and cold storage on ships, the Mediterranean countries were enabled profitably to export oranges to Australia, and it was in these shipments of fruits that the fruit fly reached Australian shores and became established about Perth and Sydney.

Establishment in Hawaii at Honolulu followed naturally the commercial jump of the pest from the Mediterranean countries to Australia. Honolulu is a port of call for ships plying between eastern Australian ports and San Francisco and Vancouver, and the voyage of about two weeks required for passage from Australia to Honolulu is through a tropical climate permitting rapid development of the fruit fly. No one ever will know just how the pest reached Honolulu on these vessels from Australia, but in view of the rigid inspection service of the Hawaiian Board of Agriculture it seems probable that larvæ falling from infested fruits in the ships' stores—in those days often kept on deck—transformed to the winged adult stage by the time of arrival at Honolulu. From 7 to 10 years ago trees bearing fruits in which the fruit fly could develop grew in greater abundance within a stone's throw of the docks than at the present time and offered an excellent breeding place for stray adults flying from the ships during the time these were in port. There is probably no port in the world where conditions were so favorable for the establishment of this particular pest as was that of Honolulu 10 years ago.

## LOSSES INCURRED THROUGH THE FRUIT FLY.

The economic importance of the Mediterranean fruit fly as a pest of fruits varies with the climate of its natural abode, or habitat. Thus, in France, near Paris, where it has been known to attack apricots and peaches, it has not become a serious pest, because of climatic checks. Such checks to the severity of its attacks have been noted in portions of Australia, South Africa, and elsewhere, and would be operative in continental United States except in portions of California and the Southern States. On the other hand, in tropical and semitropical countries the fruit fly is capable of becoming a pest of first importance, and, as in the Hawaiian Islands, may be classed as the most important insect pest to horticultural development.

Practically every fruit crop of value to man is subject to attack by this fruit fly. Not only is it of importance as a destroyer of fruit, but it is the cause of numerous stringent quarantines which cost the State and Federal Governments much money to make effective and which rob countries of good or prospective markets for their fruit. Fortunately, it has been found that the Chinese banana and the pineapple, the two most valuable species of fresh fruits formerly

exported from Hawaii, offer so little danger as carriers of the Mediterranean fruit fly, when they are packed for shipment, that this part of Hawaii's export trade in fresh fruits with the coast may still be carried on, provided the inspections of the Federal Horticultural Board now in force are continued. The necessary quarantines against all other host fruits, however, particularly against such fruits as the avocado and mango, has had, and will continue to have, a serious effect upon horticultural pursuits and the development of the small farmer.

FIG. 4.—Apples destroyed by larvæ of Mediterranean fruit fly. Although an apple externally may appear normal aside from the dark spots where the female fly punctured the skin in laying her eggs, the pulp is often found badly decayed and eaten out by the maggots, as shown in the lower fruit. (Original.)

At present the infestation of edible fruits in the coastal regions of Hawaii is general and about as severe as could be expected. The work of the Mediterranean fruit fly, with that of the melon fly, has put a most serious check upon the horticultural development of the islands just at a time when this development was gathering strength. In South Africa the Mediterranean fruit fly is regarded as one of the greatest drawbacks to the development of the fruit industry in Cape Colony, where, it is stated, during certain favorable seasons large areas of apricots, figs, pears, plums, apples (fig. 4), and quinces are almost all affected. Many instances of damage to citrus and other crops in southern Europe, South America, Africa, and Aus-

tralia might be added to impress one unfamiliar with the ravages of this pest that it is one that can not be trifled with. The amount of damage which would result through the introduction of this fruit fly is so great that every effort should be taken to prevent its establishment in new territory.

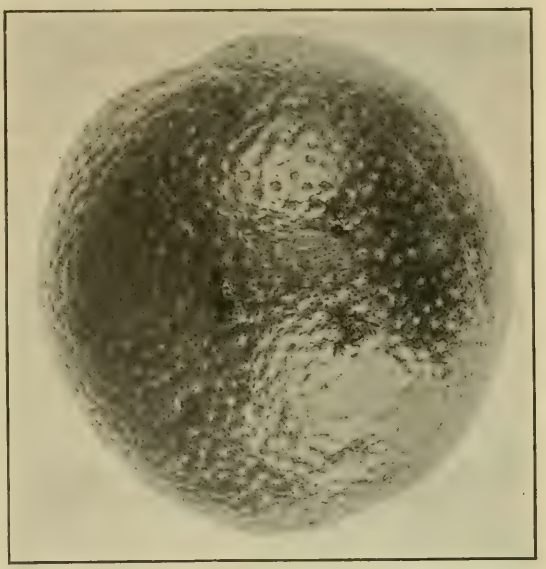

FIG. 5.—Three adults of the Mediterranean fruit fly on a sweet orange. About two-thirds natural size. (Authors' illustration.)

## WHAT THE MEDITERRANEAN FRUIT FLY IS LIKE.

*The adults.*—The Mediterranean fruit fly is an insect that in the adult stage resembles in size and general shape the ordinary house fly, but differs greatly in the color pattern of the body and wings and in its habits. In figure 5 three adults may be seen attempting to lay eggs in an orange. The glistening black spots upon the insects' back, the two white bands on the yellowish abdomen, and the yellow and black markings of the wings at once distinguish this fruit fly from all other insects in Hawaii. The colors, brown, yellow, black, and white, predominate and form a pattern that can be recognized easily after comparison with the drawing of the adult fly (fig. 1).

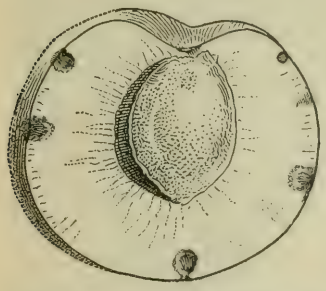

FIG. 6.—Cross section of a small apricot showing eggs laid through skin in five places. (Authors' illustration.)

*The eggs.*—The female fly is able to drill, with the sharp end of her body, small pinhole-like breaks or punctures in the skin of fruits, and through these punctures she lays her eggs. Naturally, these egg punctures are so small that they are not seen by the average person. Ordinarily the fly lays from one to six eggs through these holes into a small cavity made for them just beneath in the pulp or rind. In some instances several hundred of the small white eggs, which are only about one-twenty-seventh of an inch long and shaped as those illustrated in figures 6, 7, and 21, may accumulate in a single

egg cavity as the result of repeated egg laying by many females through the same opening in the skin.

*The larvæ.*—The eggs hatch into whitish larvæ, or maggots, that burrow or tunnel in all directions through the pulp, feeding as they go and causing decays to start. When first hatched they are very difficult to detect, but when full grown they are very white and, although only four-sixteenths to five-sixteenths of an inch long, are quite easily seen. Full-grown maggots have the peculiar habit, if taken out of the fruit and placed upon a smooth surface, of curling up and jumping from 1 to 6 inches. For the general appearance of the larvæ see figures 8 and 9, *a*.

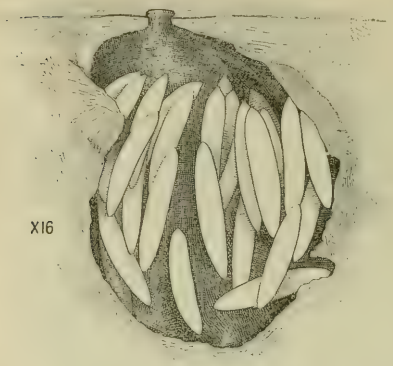


FIG. 7.—Cross section of peach showing general shriveling of walls of egg cavity and separation of eggs. Drawing made one and one-half days after eggs were laid. (Authors' illustration.)

*The pupæ.*—After leaving the fruit upon which they have fed, the larvæ either burrow into the soil to depths varying up to 2 inches or seek shelter under any object upon the ground and there transform to the pupa or chrysalis stage. During this stage the insect is not able to move and resembles the seedlike object illustrated in figure 9, *b*. Although outwardly appearing quite dead, inwardly the wonderful changes are taking place by means of which nature transforms the ugly maggot into the beautiful fly; and in the course of a few days the adult fly breaks forth from the pupa, pushes her way up through the soil, and, as the mother of a second generation, flies back to the tree and searches for fruits in which to lay her eggs.

FIG. 8.—Small mango fruit cut to show white larvæ or maggots of Mediterranean fruit fly and damage they have caused. (Severin.)

### INTERESTING FACTS ABOUT THE ADULT FLY.

Incapable of inflicting bodily injury on man, the adult fly is, nevertheless, the fruit growers' most persistent enemy in Hawaii, for she is continuously searching for fruits in which to lay her eggs. Adults die within three to four days if they have

no food; but if they can secure the juices of fruits or the honeydew of insects, which form the bulk of their food, they may live long periods. Two flies lived for 230 and 315 days, respectively. But as a rule life is much shorter, although many live to be four to six months old. Many die when they are very young, even if they have had food.

In Honolulu females begin to lay eggs when 4 to 10 days old, and, like hens, only much more faithfully, continue to develop and lay eggs in fruits almost daily so long as they live. A female may lay on an average from 4 to 6 eggs a day, 22 eggs being the largest number known to have been laid by a fly during any one day. On 10 consecutive days one fly laid 8, 11, 9, 6, 8, 3, 3, 3, 3, and 9 eggs; another laid 0, 5, 14, 8, 13, 10, 6, 4, 4, and 0 eggs. The largest number of eggs laid during life by a single female kept in the labo-

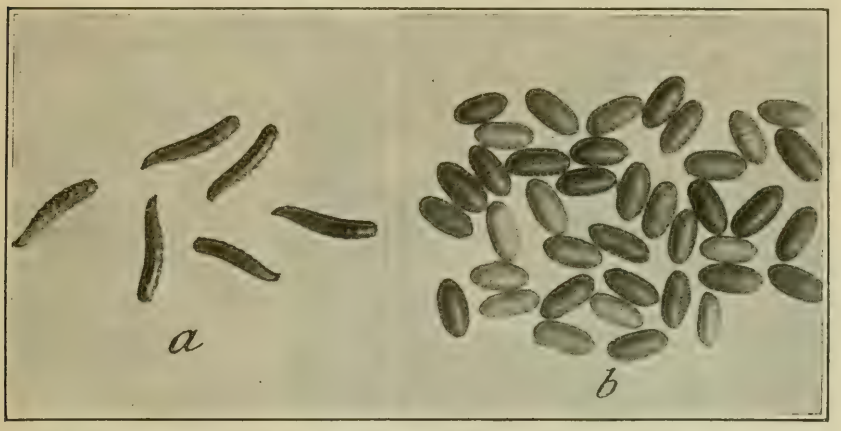


FIG 9.—Mediterranean fruit fly: *a*, Larvæ, or maggots; *b*, pupæ, or chrysalids. Twice natural size. (Original.)

ratory was 622. This fly lived only 153 days. It is probable that 800 eggs, or even more, may be laid by single hardy females under favorable conditions.

It is also important, from the standpoint of control, to know that females deprived of a chance to lay eggs in fruits for a period of four to six months when certain crops are not in season have the power to begin depositing eggs as actively as younger flies when fruits sufficiently ripe become available for oviposition. Thus one female kept in the laboratory for the first five months of her life without fruits in which to lay eggs laid 11, 4, 9, and 9 eggs during the first four days of the sixth month of her life when fruits were placed in the cage with her.

### CLIMATIC CONDITIONS FAVORING RAPID INCREASE IN HAWAII.

The time required by the fly to pass through the egg, larva, and pupa stages depends very much upon the climate. The climate of Honolulu and of the coastwise regions of Hawaii in general is very

favorable to fruit-fly increase. At Honolulu the temperature rarely drops as low as 58° F., and then only for a few hours during one or two nights in the year. The daily range in temperature is small, averaging between 8 and 11 degrees, while the normal monthly mean temperatures range between 70.9° F. in the winter and 79° F. in the summer. Biological work has shown that even the lowest monthly means of localities up to 1,500 feet elevation have little effect upon the fruit fly other than to retard somewhat its development. It is never cold enough throughout the coastal regions of Hawaii to render either the adults or the larvæ inactive. There are no periods of the year at any Hawaiian port when climatic conditions are unfavorable for fruit-fly increase. A continuous temperature of 58° to 62° F., or the lowest range of temperature usually experienced, does not increase the normal mortality among the larvæ.

FIG. 10.—Three important edible fruits subject to fruit-fly attack: *a*, Strawberry guava; *b*, loquat; *c*, star apple. These are grown also for their ornamental value. (Original.)

#### LENGTH OF TIME REQUIRED FOR DEVELOPMENT.

During the warmest Hawaiian weather, when the mean temperature averages about 79.5° F., the Mediterranean fruit fly requires as few as 17 or as many as 33 days to pass through its immature stages.

At this season by far the larger number pass through these stages in 18 to 20 days. At an average mean temperature of 68° F., which is about the coolest temperature in Hawaii where fruits are generally grown, the immature stages require 40 to 69 days.

Just what the length of the immature stages may be in cooler regions can not be definitely stated, but experiments indicate that it may be considerably increased. The egg stage has been increased from a normal of 2 days at Honolulu in summer to 25 days by the application for 22 days of a temperature of 48° to 53° F. A well-grown larva survived a temperature of 48° to 54° F. for 79 days. A newly-hatched larva remained practically dormant for 57 days at an out-of-door temperature ranging from 27° to 73° F. (mean 48° F.), whereas in Honolulu during summer it would have remained in this stage only 2 days. The fruit fly has been held in the pupa stage for about two months at an out-of-door temperature ranging between 38° and 72° F. (mean, about 54° F.). Had the mean been about 79° F., it would have remained in the pupa stage only 9 to 11 days. Three larvæ in very firm apples required 28, 58, and 74 days to become full grown and leave the fruit to pupate at Kealakekua, where the temperature ranged between 58° and 80° F. (mean, about 68° F.). Add to the 74 days required for larval maturity 4 days for the egg stage and 20 days for the pupa stage, and one has 98 days, or over three months, as the time required for the fly to pass through the immature stages under certain host conditions at a mean of 68° F. Thus while these stages may be completed in as few as 17 days, three to four months is a very conservative estimate for possible length under less favorable climatic conditions, or a period sufficiently long to outlast the coolest seasons of the semitropics.

## FRUITS, NUTS, AND VEGETABLES ATTACKED.

The Mediterranean fruit fly is particularly injurious because it attacks so many more different kinds of fruits of value to man than does any other known fruit fly. In the Hawaiian Islands 72 kinds of fruits have been found infested. Fortunately, the pineapple is not infested, and the banana is free from attack when shipped under commercial conditions. The fruit fly has been reared from the following fruits: Fruits that are heavily or generally infested are marked (1), those that serve quite often as hosts or of which many escape infestation are marked (2), and those rarely infested are marked (3).

*List of host fruits of the Mediterranean fruit fly.*

| | SCIENTIFIC NAME. | COMMON NAME. |
|---|---|---|
| 1. | *Achras sapota* (3) | Sapodilla. |
| 2. | *Acordia* sp. (3) | Acordia. |
| 3. | *Anona muricata* (2) | Sour sop. |
| 4. | *Arengia saccharifera* (3) | Sugar palm. |
| 5. | *Artocarpus incisa* (3) | Breadfruit. |
| 6. | *Averrhoa carambola* (2) | Carambola. |
| 7. | *Calophyllum inophyllum* (1) | Ball kamani. |
| 8. | *Capsicum* sp. (2) | Bell peppers (fig. 17, p. 19). |
| 9. | *Carica papaya* (2) | Papaya. |
| 10. | *Carica quercifolia* (2) | Dwarf papaya. |
| 11. | *Carissa arduina* (2) | Carissa (fig. 11, *h*). |
| 12. | *Casimiroa edulis* (1) | Sapota. |
| 13. | *Cestrum* sp. (3) | Chinese inkberry. |
| 14. | *Chrysophyllum cainito* (1) | Star apple (fig. 10, *c*). |
| 15. | *Chrysophyllum oliviforme* (1) | Damson plum (fig. 11, *d*). |
| 16. | *Chrysophyllum* sp. (1) | Chrysophyllum. |
| 17. | *Citrus japonica* (1) | Chinese orange (fig. 18, p. 20). |
| 18. | *Citrus japonica* (1) | Kumquat. |
| 19. | *Citrus nobilis* (1) | Tangerine. |
| 20. | *Citrus nobilis* (1) | Mandarin. |
| 21. | *Citrus medica limetta* (1) | Lime. |
| 22. | *Citrus medica limonum* (1) | Lemon (fig. 19, p. 21). |
| 23. | *Citrus decumana* (1) | Grapefruit (figs. 2, 20, 21, 22, pp. 3, 22, and 23). |
| 24. | *Citrus decumana* (1) | Shaddock. |
| 25. | *Citrus aurantium* (1) | Sweet orange. |
| 26. | *Citrus aurantium* var. *amara* (1) | Sour orange. |
| 27. | *Clausena wampi* (3) | Wampi. |
| 28. | *Coffea arabica* (1) | Coffee (fig. 11, *b*). |
| 29. | *Coffea liberica* (1) | Liberian coffee. |
| 30. | *Cydonia vulgaris* (1) | Quince. |
| 31. | *Diospyros decandra* (1) | Persimmon. |
| 32. | *Eriobotrya japonica* (1) | Loquat (fig. 10, *b*). |
| 33. | *Eugenia brasiliensis* (1) | Brazilian plum or Spanish cherry. |
| 34. | *Eugenia jambos* (1) | Rose apple (fig. 11, *g*). |
| 35. | *Eugenia michelii* (1) | Surinam cherry. |
| 36. | *Eugenia uniflora* (1) | French cherry. |
| 37. | *Ficus carica* (1) | Fig. |
| 38. | *Garcinia mangostana* (2) | Mangosteen. |
| 39. | *Garcinia xanthochymus* (2) | Mangosteen. |
| 40. | *Gossypium* spp. (2) | Cultivated cotton (fig. 11, *e*) |
| 41. | *Jambosa malaccensis* (2) | Mountain apple. |
| 42. | *Lantanis placuachulla* (3) | Palm. |
| 43. | *Lycopersicum esculentum* (2) | Tomato. |
| 44. | *Litchi chinensis* (3) | Lichee nuts (fig. 11, *c*). |
| 45. | *Mangifera indica* (1) | Mango (figs. 8, 24, pp. 8 and 25). |
| 46. | *Mimusops elengi* (1) | Elengi tree (fig. 11, *i*). |
| 47. | *Murraya exotica* (1) | Mock orange (fig. 11, *f*). |
| 48. | *Musa* spp. (3) | Banana (figs. 14 and 15, p. 17). |
| 49. | *Noronhia emarginata* (3) | Noronhia. |
| 50. | *Ochrosia elliptica* (2) | Ochrosia. |

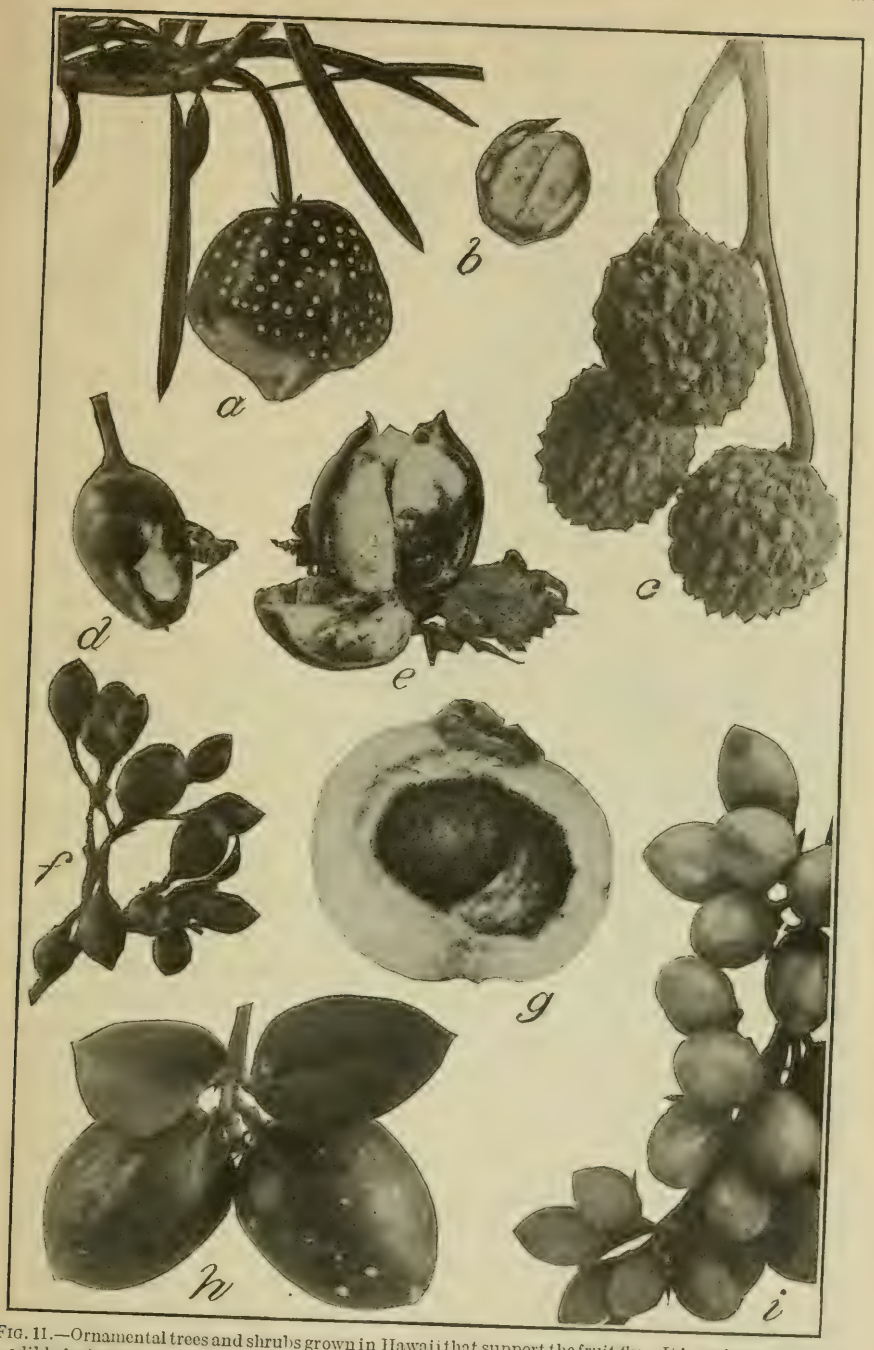


FIG. 11.—Ornamental trees and shrubs grown in Hawaii that support the fruit fly. It is useless to protect edible fruits when ornamentals are allowed to grow near by that harbor the fruit fly: *a*, The bestill, showing drops of white sap that exude when the fly punctures the skin; *b*, a coffee cherry sectioned to show the maggots feeding on the pulp; *c*, the lichee nut is not attacked by the fly unless the outer skin has broken; *d*, a damson plum, showing an adult fly caught in the sticky sap; *e*, a cotton boll infested by the pink bollworm and the fruit fly; *f*, a cluster of mock-orange berries; *g*, a rose apple sectioned to show fruit-fly attack; *h*, the carissa, showing drops of white sap that have exuded from punctures made in the skin by the fruit fly; *i*, the elengi berries, that develop many fruit flies.

51. *Opuntia vulgaris* (2)..... Prickly pear.
52. *Passiflora* sp. (3)..... Passion vine.
53. *Persea gratissima* (2)..... Avocado (fig. 13).
54. *Phoenix dactylifera* (3)..... Date palm.
55. *Psidium cattleyanum* (1)..... Strawberry guava (fig. 10, *a*).
56. *Psidium guayava* (1)..... Sweet red and white lemon guavas.
57. *Psidium guayava pomiferum* (1)..... Common guava.
58. *Psidium guayava pyriferum* (3)..... Waiawi.
59. *Prunus persica* (1)..... Peach (fig. 7, p. 8).
60. *Prunus persica* var. *nectarina* (1)..... Nectarine.
61. *Prunus armeniaca* (1)..... Apricot (fig. 6, p. 7).
62. *Prunus* spp. (1)..... Plum.
63. *Punica granatum* (3)..... Pomegranate.
64. *Pyrus* spp. (1)..... Apple (fig. 4, p. 6).
65. *Pyrus* spp. (1)..... Pear (fig. 12).
66. *Solanum melongena* (3)..... Eggplant.
67. *Spondias dulcis* (3)..... Wi.
68. *Terminalia catappa* (1)..... Winged kamani or tropical almond.
69. *Terminalia chebula* (1)..... Natal plum.
70. *Thevetia neriifolia* (1)..... Bestill (fig. 11, *a*).
71. *Vitis labrusca* (3)..... Grape (fig. 25, p. 26).
72. *Santalum freycinetianum* var. *littorale* (3)..... Beach sandalwood.

This list shows that practically all the ordinary useful and edible fruits in Hawaii are infested heavily. Thus peaches can not be grown at present, for they are ruined before they become well grown; Chinese oranges (fig. 18), tangerines, figs, loquats (fig. 10, *b*), rose apples (fig. 11, *g*), many varieties of mangoes (figs. 8, 24), certain avocados (fig. 13), guavas (fig. 10, *a*), coffee cherries (fig. 11, *b*), star apples (fig. 10, *c*), sapotas, persimmons, apples (fig. 4), pears (fig. 12), plums, nectarines, and quinces—all these are badly infested. On the other hand, a large percentage of the ripening fruits of the tomato, prickly pear, mangosteens, mountain apples, and wampis are free from attack, although certain fruits may be at times heavily infested. When tomatoes are wormy, the melon fly, and not the Mediterranean fruit fly, is usually the insect doing the damage. Ordinarily, sweet bell peppers are not generally infested, and cotton bolls become infested only after they have been damaged by some other insect (figs. 17 and 11, *e*).

The pomegranate, breadfruit, eggplant, wi, grape (fig. 25), date, certain seeds of palms, lichee nuts (fig. 11, *c*), and the Chinese inkberry are very rarely infested, even in Honolulu. For practical purposes they may be said to be immune. Lichee nuts ripening on the tree become infested only when the outer shell breaks, thus exposing the white pulp to attack.

Hawaiian fruits, nuts, and vegetables not listed are free from attack.

### ORNAMENTALS SERVING AS HOSTS.

Not only does the Mediterranean fruit fly attack the ordinary cultivated fruits, but in Hawaii it has shown a preference for the fruits of many ornamental trees and shrubs. Thus the nuts of the winged kamani, the ball kamani, the rose apple, damson plum, star apple, Brazilian plum or Spanish cherry, the Surinam and French cherries, the berries of the mock orange and elengi tree, the fruits of the Natal plum, and the mature fruits of the bestill are all usually well infested. Even the fruits of certain palms and the beach sandalwood may harbor the fly. Ornamentals less subject to attack may be found in the foregoing complete list.

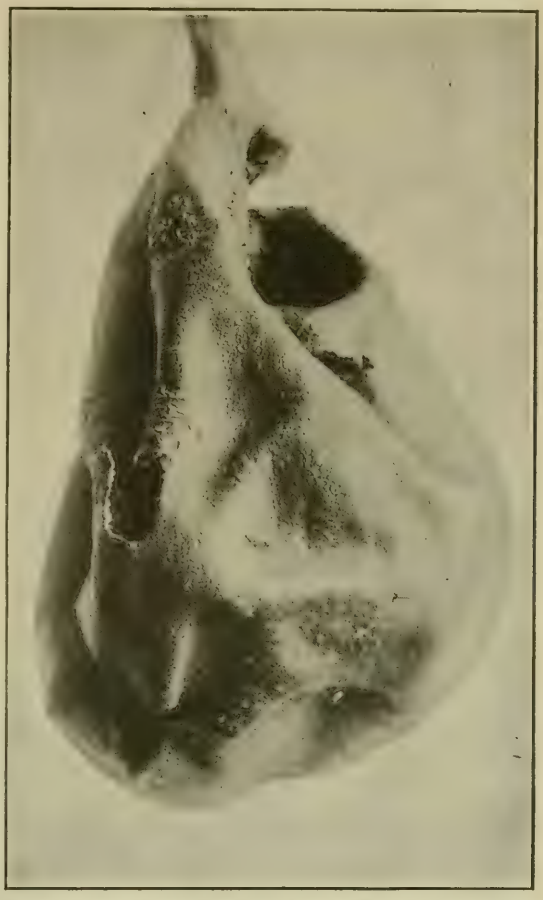

FIG. 12.—Bartlett pear, the pulp of which has been entirely eaten out by the maggots of the Mediterranean fruit fly. The fruits often remain on the tree and shrivel up after they have been ruined. (Authors' illustration.)

## HOST FRUITS OF COMMERCIAL VALUE.

### PINEAPPLES.

Many experiments have been carried on to determine whether the Mediterranean fruit fly can live in the pineapple. It has been found that even under forced laboratory conditions the fly can not live or mature in green or ripe pineapples. No person has ever found a pineapple infested by this pest in Hawaii.

### PAPAYAS.

The papaya is one of the commonest plants about Honolulu. Its fruit is the universal breakfast fruit. Probably not one person in a thousand in Honolulu, however, knows that papayas become infested. Unless the fruits are allowed to remain upon the trees until overripe,

the fruit fly can not mature in them. The milky juice, which exudes copiously from breaks in the skin of the fruits up to the time when the fruits can be cut for ripening in the house, contains a digestive principle that is fatal to the eggs and larvæ of the fly. This juice protects the fruits from infestation when immature. But as the fruits become overripe, and also unfit for the table, the juice flows less abundantly from breaks in the skin made by the fly when she attempts to lay her eggs, and the eggs which she then lays can mature. As many as 205 flies have been reared from single overripe fruits. So while the papaya is a host fruit, it is practically never infested until too ripe or otherwise unfit for the table.

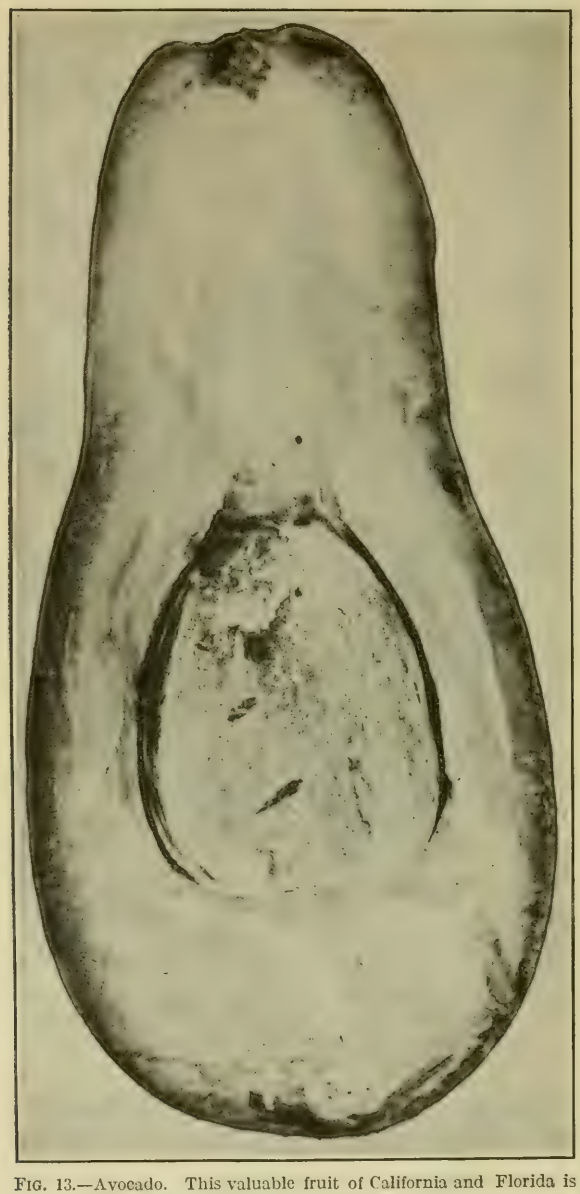

FIG. 13.—Avocado. This valuable fruit of California and Florida is subject to infestation in Hawaii. In this instance the maggots are working at the stem and blossom ends. (Authors' illustration.)

#### AVOCADOS.

With the exception of one or two early varieties, the infestation of the avocado is so obscure that the general belief prevails in Honolulu that this fruit is free from attack. The Guatemala, or nutmeg, variety is the only one free from attack when growing uninjured. The skin of all other varieties, whether thin or of usual toughness, can be punctured by the adult fly, as proved by many examinations of fruits. The avocado, like the ordinary pear, is best when picked

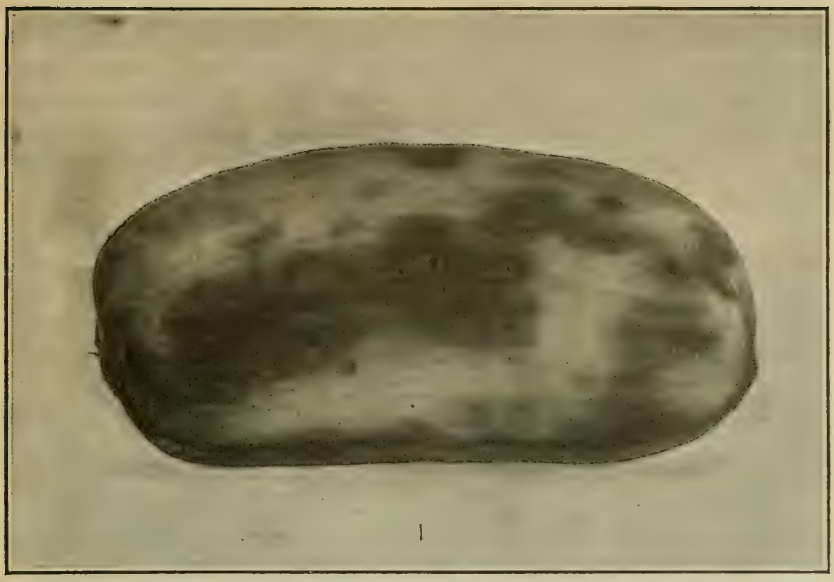


FIG. 14.—Cooking banana of the Popoulu variety taken from tree in an infested condition. Note small round holes in the skin through which maggots left the fruit when they became full grown. (Authors' illustration.)

FIG. 15.—Cooking banana of the Moa variety cut to show destruction of pulp by maggots of the Mediterranean fruit fly. (Authors' illustration.)

while still hard, though mature, and allowed to soften in storage. With most varieties it is not until the fruits are mature enough for gathering or dropping that adults lay eggs in them. Many fruits upon the market are not in the least affected. While avocadoes are not usually a favorite host for the fly, they are sufficiently infested to warrant the quarantine prohibiting the shipment of them to the mainland. (See fig. 13.)

BANANAS.

Experimentation during the past four years in Hawaii has proved that the Chinese banana[1] and the Bluefields banana[2] are practically immune from attack if harvested and shipped to the coast in accordance with the demands of the trade and the Federal Horti-

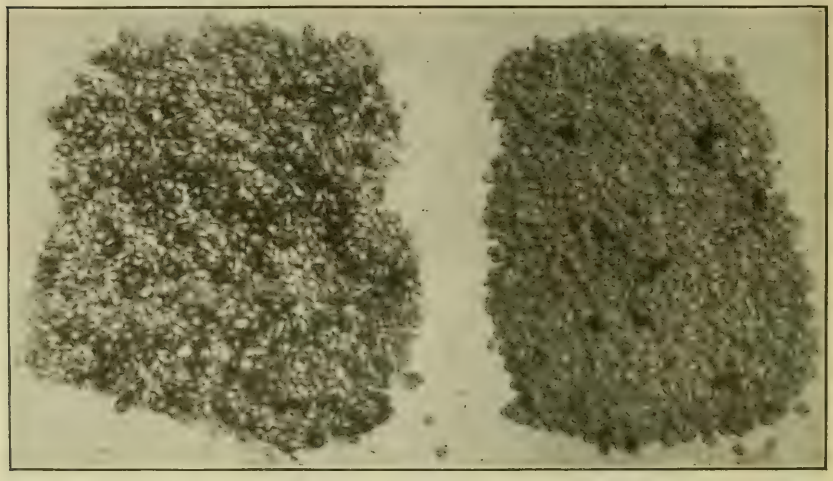

FIG. 16.—Loss to coffee-mill owners due to infestation of coffee cherries by Mediterranean fruit fly. Coffee beans to left pulped from uninfested cherries; beans to right pulped from infested cherries. Cherries failing to pulp, because infested, appear as black; pulped beans are grayish white. (Original.)

cultural Board. Persons wishing the results of careful experimental work used as a basis for these conclusions may obtain them in printed form by applying to the Bureau of Entomology. The immunity of commercial varieties of bananas has been shown to be due to the fact that neither the eggs nor the newly-hatched larvæ can survive in the tannin-laden peel of the green though mature fruit. Indeed, the copious and sudden flow of sap from egg punctures made by the female fly in unripe bananas renders the successful placing of eggs in such fruits difficult and rare.

No fruits of the Chinese variety ripening prematurely on bunches in plantations have been found infested. But of the cooking bananas, flies have been reared from the ripe and yellowish fruits of the thin-skinned Popoulu variety (fig. 14) growing in the field, and from the

[1] *Musa cavendishii.* [2] *Musa sapientum.*

well-grown though green-colored fruits of the Moa variety, the peel of which had become cracked, thus causing a break in nature's normal protection to the pulp. Figure 15 is a cross section of a Moa banana, showing the tunnels made through the pulp by the larvæ, and the darkened decayed areas about the tunnels. Adults have been reared also from another variety of cooking bananas.

Because flies have been reared from cooking bananas, it is not considered safe to permit their export to the coast, and they have been placed on the list of quarantined fruits by the Federal Horticultural Board. The Chinese and Bluefields bananas may still be exported from Hawaii, provided they are grown and inspected before shipment in accordance with Federal regulations. So far as is known, the "apple" and the "ice-cream" bananas common in Hawaii are not infested.

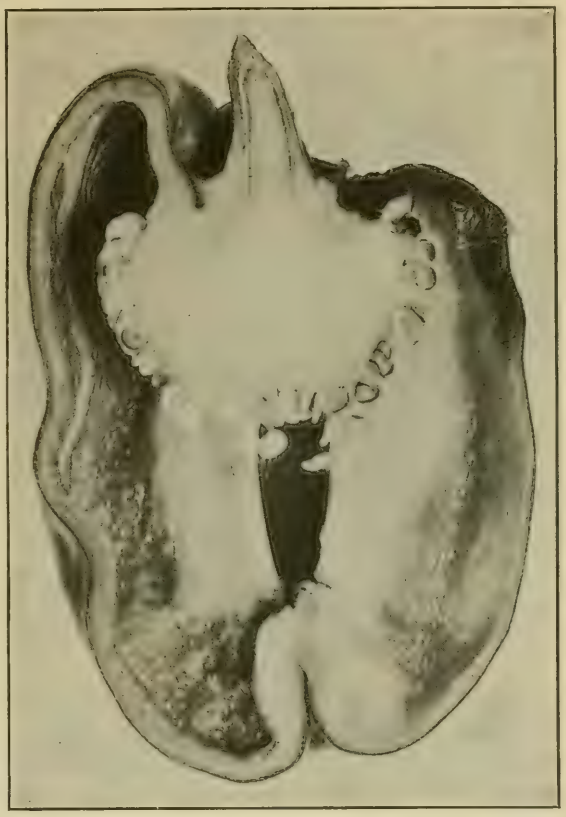

FIG. 17.—Sweet bell pepper infested by Mediterranean fruit-fly larvæ. Note that the upper right-hand portion of fruit has decayed as a result of attack. This decay later extends to all parts of the fruit. (Original.)

### COFFEE.

Coffee cherries as they ripen are favorite hosts of the Mediterranean fruit fly. Fortunately, the larvæ attack only the pulp surrounding the beans or seeds, and in no way affect the value of the latter (see fig. 11, *b*). Chemical analyses of beans from infested and uninfested cherries, tasting tests of coffee made from similar roasted beans, and weighings made of dried beans have failed to reveal any ill effect to the beans themselves due to fruit-fly attack.

The unrestricted development of larvæ within coffee cherries, however, does bring about certain losses to the grower and mill owner. Before parasites were introduced cherries became infested

as soon as they began to turn white from green in the final ripening process, and the larvæ, numbering from 2 to 8, were able to become nearly full grown by the time the cherries had turned red. The pulp surrounding the beans varies from two to seven fifteenths of an inch in thickness, or is scarcely thicker than the well-grown larva of the fruit fly (see fig. 30, p. 39). Therefore, by the time the cherry is ordinarily ready for harvesting, the larvæ have devoured practically all the pulp, leaving the seeds hanging more or less loosely within a sack comprised of the thin skin of the cherry. If the weather happens to be dry, the skin shrivels and hardens about the beans and the cherry remains on the branch indefinitely and resembles those killed by disease. However, should the harvesting season be rainy, the skin decays rapidly, and under the weight of the beans the cherry falls to the ground. A slight jar may at such times cause many cherries to fall to the ground, where they are lost. This type of loss necessitates extra pickings and greater cost for labor. Since the successful introduction of parasites the fruit fly has been so reduced in the coffee field that the infestation of cherries occurs so late in the ripening process that extra pickings are not necessary, and the cherries on reaching the pulping mills during the height of the harvesting season contain chiefly eggs or young larvæ which have not had an opportunity to reduce the pulp.

FIG. 18.—Chinese orange sectioned to show damage by Mediterranean fruit fly. Chinese oranges, kumquats, tangerines, satsuma oranges, and many limes are easily and generally infested because of their loose peel and lack of a thick protective rag. (Original.)

Badly infested cherries do not pulp as readily when run through the pulping mill, and naturally weigh much less than sound cherries. (Fig. 16.) The loss in number of cherries in a given weight of badly infested fruit has been found to vary at times from 27 to 59 per cent. This loss in weight, which takes place only in the worthless pulp, and in no way affects the bean, which alone is of commercial value, brought about a financial loss to growers who sold their fruit by weight according to prices obtained before the fruit fly was intro-

duced. This has been appreciated and has caused a readjustment of prices paid for coffee "in the cherry" and has been responsible for the erection of many small pulping mills throughout the Kona coffee district.

It seems reasonable to believe that the remarkable success of introduced parasites in checking the infestation of coffee will free the coffee grower from further worry so far as the Mediterranean fruit fly is concerned.

FIG. 19.—Lemons of commercial varieties have never been found with larvæ of the Mediterranean fruit fly destroying the pulp unless they have had the rind cut or broken previous to attack. The adult flies may puncture the skin and lay eggs, as indicated by the discolored spots, but the eggs and larvæ die in the peel. (Original.)

### CITRUS FRUITS.

While all citrus fruits are favorite hosts of the Mediterranean fruit fly, certain of them are found to contain larvæ more often than others. No citrus fruits are too acid for fruit-fly development. Larvæ have been reared from the sourest lemons. Adult flies are fond of laying eggs in large numbers in all citrus fruits. Thus 13 punctures in one grapefruit contained 76, 153, 32, 25, 18, 8, 46, 113, and 9 eggs, respectively. Thirty-nine oranges, either yellow or orange in color, contained an average of 32 egg punctures, with a maximum of 108 and a minimum of 7 punctures. In 50 ripe lemons 1,422 eggs were laid in 185 punctures. Yet no adult flies developed from this grapefruit or from the oranges and lemons. On the other hand, well ripened Chinese oranges (fig. 18), thin-skinned limes, kumquats, and tangerines are so generally infested with larvæ in the pulp before they become well ripened that they are always regarded with suspicion.

Although many eggs are laid in lemons, it is rare that lemons are found with maggots in the pulp even when the fruits are so ripe

FIG. 20.—Ripe grapefruit showing copious gummy secretions that may, though more often do not, follow attack by Mediterranean fruit fly. (Original.)

that they fall to the ground. Why, then, are Chinese oranges and tangerines easily infested with larvæ in the pulp whereas lemons, grapefruit, and oranges ward off fatal attack either entirely or until after they are overripe?

The reason is that a great mortality occurs among the eggs and newly hatched larvæ in citrus fruits having a thick peeling or rind. In Chinese oranges the peel is so thin that the fruit fly can lay her eggs through it into the pulp itself or between the pulp and the rind, so that the larvæ on hatching can at once begin to feed on the pulp. As a result the pulp of the Chinese orange (fig. 18) is almost always infested with larvæ. The case is different with lemons (fig. 19), grapefruit (fig. 20), and ordinary seedling oranges. In these fruits the peel is so thick that the fly must deposit her eggs in the outer part of the white rag as illustrated in figure 21. In making the puncture she often ruptures an oil cell in the rind, and the oil thus liberated kills the eggs. But if the eggs are laid between oil cells, the young larvæ have difficulty in making their way through the rag to the pulp, and a very high percentage of them die in the attempt.

Then, too, a gall-like hardening develops quite rapidly about the egg cavity in oranges, grapefruit, and lemons, as indicated by the darkened area about the egg cavity in figure 21. This hardening often makes of the cavity a prison from which the young larvæ can not escape and in which they are literally starved to death.

It thus happens that the larvæ that succeed in entering the rag of the peel from the egg cavity are able to reach the pulp of grapefruit

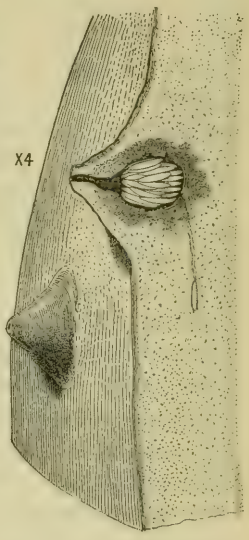


FIG. 21.—Section of grapefruit rind, showing two egg cavities, one in cross section. Drawing made one week after fruit was picked. Note conical elevation about egg cavities left by withering of rind; also thickened walls of egg cavity and single larval channel in the rag. (Authors' illustration.)

and oranges in astonishingly small numbers because of the impervious-ness of the rag. It is the persistent attack of successive families of larvæ hatching from different batches of eggs laid in the same punctures that finally breaks down the barrier between the young larvæ and the pulp. A fuller discussion of the infestation of all citrus fruits may be had on application to the Bureau of Entomology.

Regardless of what has just been stated concerning the great mortality that occurs among the eggs and young larvæ in the rind

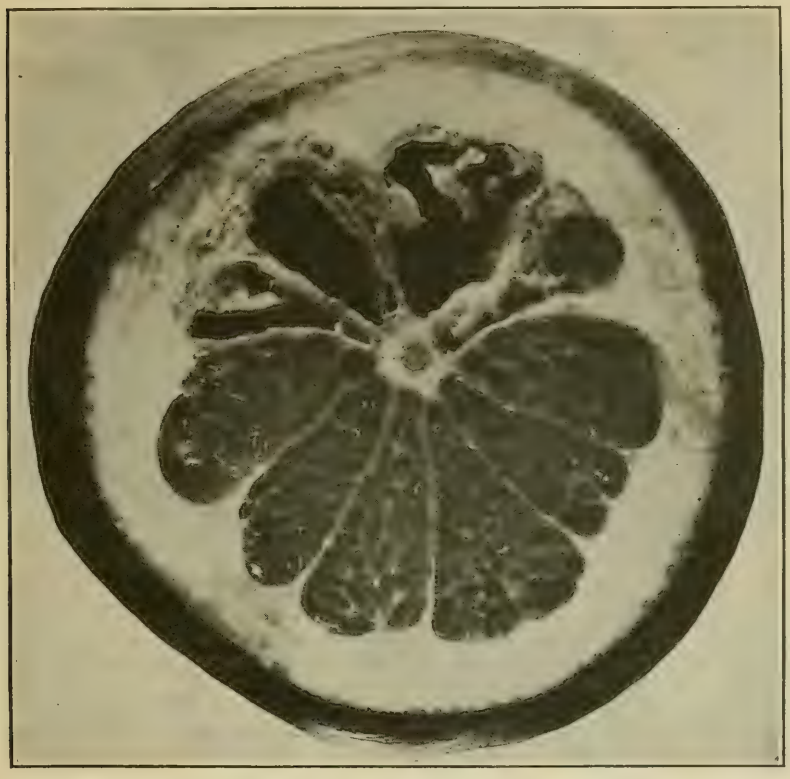

FIG. 22.—Cross section of grapefruit to indicate difficulty of always telling from exterior appearance of a fruit that maggots are eating out the pulp. (Authors' illustration.)

of grapefruit, oranges, and lemons, adult flies have been reared from them all. Lemons, however, have never been known to be infested in the pulp unless the rind has first become broken by thorn pricks, decays, or in some other mechanical manner. And in spite of the fact that oranges and grapefruit may become very wormy, as illustrated in figures 2 and 22, they are usually uninfested in the pulp, and are fit for table use if they are gathered as soon as they ripen. But if citrus fruits were grown commercially in Hawaii in large

orchards as they are in Florida and California, and were severely attacked as they are in Hawaii to-day, they could not be shipped profitably, for, although they might not contain larvæ within the pulp, the many breaks in the rind made by the flies while laying eggs would make possible the entry of various molds (see fig. 23) that

FIG. 23.—Orange injured by Mediterranean fruit fly. Each black spot represents a place where the fruit fly has punctured the rind to lay eggs, but the maggots were not able to eat through the peel, and died. About the injured spot decays have started which at first affect only the peel. Blue mold grows rapidly in these injured spots. (Original.)

would cause unprecedented decays while the shipments were en route to market.

## ARTIFICIAL METHODS OF CONTROL NOT SATISFACTORY UNDER HAWAIIAN CONDITIONS.

It is unfortunate that the satisfactory methods of control used against the Mediterranean fruit fly in several other countries, particularly in portions of South Africa and Australia, have failed in Hawaii. There are, however, several good reasons for such failures. The great money-making crops of Hawaii at present are sugar, pineapples, rice, coffee, taro, bananas, and cattle. But sugar, pineapples, and taro are not attacked by this fruit fly, and, as already shown, coffee and bananas are not sufficiently attacked to injure their commercial value. With one exception, including a small number of

avocados, no commercial orchards exist in Hawaii. Still there is hardly a family, unless it be in the business section of Honolulu, that does not grow a number of fruit trees, such as oranges, lemons, papayas, peaches, avocados, limes, grapefruit, guavas, bananas, mangoes, etc., that bear prodigally under normal Hawaiian cultural conditions, and, until the advent of the fruit fly in 1910, formed a most welcome addition to the food supply.

Much of the native-grown fruit that is sold in the local market is grown on trees scattered here and there in dooryards and is in excess of what the owner needs. Practically no one depends on growing fruit for his living. No developed fruit industry exists such as one finds on the mainland, and no moneyed interest concerns itself with steps for fruit-fly eradication. In other words, there are no impelling incentives to solidify public opinion for the consistent and cooperative use of artificial remedial measures that could be made effective if their application would yield returns warranting the expenditure.

FIG. 21.—Improved mango sectioned to show havoc caused by maggots of Mediterranean fruit fly. (Authors' illustration.)

The situation also is made more difficult by reason of the large amount of vegetation, bearing fruits of little or no value to man, that grows throughout the islands and that can not be eradicated without the expenditure of prohibitive sums of money.

But this great abundance of dooryard and wild host vegetation has had such a vital part in the undoing of artificial control measures and in the success of parasite introductions that it is worthy of further attention. Aided by a favorable climate, it has made of Hawaii a fruit-fly paradise that is not duplicated elsewhere on the earth.

## THE CAMPAIGN AGAINST THE FRUIT FLY IN HAWAII.

### HOST CONDITIONS IN HONOLULU AND HILO.

The residents of Honolulu and Hilo are justly proud of their magnificent vegetation and have taken great pleasure in growing an

FIG. 25.—This bunch of grapes, apparently perfect, contains one berry that is decayed and contains a larva of the Mediterranean fruit fly. The Isabella grapes in Hawaii are seldom attacked, even in Honolulu, yet they are likely to carry the fly to California. (Original.)

unusually large assortment of trees and shrubs on their properties. An inventory of such trees and shrubs in the portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School Streets gave a total of 4,610 that bore fruits in which the fruit fly can develop.

TABLE II.—*Number and species of host trees of the Mediterranean fruit fly growing in that portion of Honolulu bounded by Liliha, Punchbowl, Beretania, and School Streets.*

| | |
|---|---|
| Apricot | 1 |
| Avocado | 653 |
| Breadfruit | 58 |
| Carambola | 48 |
| Chinese inkberry | 6 |
| Chinese orange | 148 |
| Coffee | 298 |
| Coffee, Liberian | 8 |
| Cotton | 11 |
| Custard apple | 1 |
| Damson plum | 4 |
| Fig | 201 |
| Guava, common | 94 |
| Guava, strawberry | 73 |
| Java plum | 80 |
| Kamani, ball | 4 |
| Kamani, winged | 13 |
| Kumquat | 4 |
| Lemon | 22 |
| Lichee | 40 |
| Lime | 10 |
| Loquat | 33 |
| Mandarin | 28 |
| Mango | 1,154 |
| Mangosteen | 7 |
| Mountain apple | 41 |
| Mock orange | 33 |
| Orange, sweet | 372 |
| Papaya | 687 |
| Peach | 69 |
| Pear, Bartlett | 2 |
| Pomegranate | 128 |
| Pomelo | 15 |
| Rose apple | 25 |
| Sapodilla | 5 |
| Sapota | 30 |
| Sour sop | 57 |
| Spanish cherry | 1 |
| Star apple | 4 |
| Surinam cherry | 63 |
| Wi | 19 |
| Waiawi | 60 |
| Total | 4,610 |

In this area of 60 blocks of varying size, 712 dooryards, or estates, averaged 6.5 host trees or shrubs.

In Hilo, island of Hawaii, host conditions are quite as favorable for fruit-fly increase as in Honolulu. Thus the following numbers of host trees and shrubs were found in certain yards during March, 1914.

| YARD 1. | |
|---|---|
| Rose apple | 1 |
| Surinam cherry | 4 |
| Japanese plum | 2 |
| Mountain apple | 6 |
| Star apple | 1 |
| Coffee trees | 34 |
| Common guava | 20 |
| Brazilian banana | 15 |
| Avocado | 4 |
| Mango | 3 |
| Papaya | 2 |
| Orange | 5 |
| Peach | 1 |
| Grape | 1 |
| Winged kamani | 1 |
| Mangosteen | 1 |
| Fig | 1 |
| Mimusops | 1 |

| YARD 2. | |
|---|---|
| Surinam cherry | 2 |
| Papaya | 2 |
| Thevetia | 1 |

| YARD 2—Continued. | |
|---|---|
| Orange | 2 |
| Strawberry guava | 2 |
| Coffee | 14 |
| Bananas. | |
| Avocado | 2 |
| Peach | 1 |
| Fig | 3 |
| Mountain apple | 2 |
| Lichee nut | 2 |
| Common guava | 3 |

| YARD 3. | |
|---|---|
| Rose apple | 11 |
| Mango | 2 |
| Thevetia | 3 |
| Avocado | 1 |

| YARD 4. | |
|---|---|
| Peach | 4 |
| Mango | 6 |
| Loquat | 1 |
| Winged kamani | 3 |
| Surinam cherry | 2 |
| Strawberry guava | 1 |

The great variety of host vegetation which ripens its fruit at different seasons leaves no time in Hawaii when fruits are entirely out of season. The fact that certain hosts, such as the Chinese orange, Surinam cherry, and mock orange, bear several crops a year and others, such as specimens of the ball and the winged kamanis and the bestill, appear to be seldom entirely free from ripening fruits, assure food for the fruit fly the year round. The succession of fruits also is increased by the individuality of trees of the same species, or even of certain branches of a single tree, which results in a very uneven ripening of the fruit. While the data in Table III do not indicate the seasonal abundance of host fruits, they have been summarized from the collections of clean-culture inspections during 1913 to show the remarkable succession of host fruits ripening in greater or less abundance throughout the year in Honolulu. The presence of so much ripening fruit, much of it on tall trees such as those illustrated in figures 26, 27, and 28, has made it possible for the fruit fly to multiply with unprecedented rapidity and thwart artificial remedial measures.

TABLE III.—*Data indicating the seasons of the year when inspectors of the clean-culture campaign collected various fruits infested by the Mediterranean fruit fly.*[1]

| Fruit. | Jan. 1–11. | Jan. 13–18. | Jan. 20–25. | Jan. 27–Feb. 1. | Feb. 3–8. | Feb. 10–15. | Feb. 17–22. | Feb. 24–Mar. 1. | Mar. 3–8. | Mar. 10–15. | Mar. 17–22. | Mar. 24–29. | Mar. 31–Apr. 5. | Apr. 7–12. | Apr. 14–19. | Apr. 21–26. | Apr. 28–May 3. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocado | | | | × | | | | × | | | | | | × | | | |
| Carambola | × | × | × | × | × | × | × | × | × | × | × | × | × | | × | × | |
| Chinese orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Chrysophyllum spp. | | | | | | | | | | | | | | | | | |
| Coffee | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Damson plum | × | × | × | × | × | × | × | × | × | × | | | | | × | × | × |
| Surinam cherry | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Fig | × | × | × | × | | × | × | × | × | × | × | × | × | × | × | × | × |
| Grapefruit | × | × | × | × | × | × | | × | × | × | × | × | | × | | | |
| Guava | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kamani, ball | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kumquat | | × | × | × | | × | × | | | | × | | | × | | | × |
| Lime | × | × | × | × | × | × | × | × | × | × | | × | × | | × | × | |
| Loquat | × | × | × | × | × | × | × | × | × | × | × | | × | × | | × | × |
| Mango | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Mock orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Mountain apple | | | × | × | × | | × | × | | × | | | | | × | × | × |
| Orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Papaya | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Peach | | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Pepper | × | × | × | | × | × | × | × | × | × | × | × | × | × | | | |
| Prickly pear | | | × | | | × | | | | | | | × | | | × | |
| Rose apple | | × | | × | × | × | × | × | × | × | × | × | | × | × | × | × |
| Star apple | | | | | | | | | | × | × | × | × | | × | | × |
| Bestill | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Sour sop | | | | × | × | × | × | × | | × | × | × | × | × | × | × | × |
| Mandarin | × | × | × | × | × | × | × | × | × | × | × | | × | × | × | × | × |
| Lemon | × | × | | × | | × | | × | × | × | × | × | | × | × | × | × |
| Kamani, winged | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Spanish cherry | | × | × | | | | | | | | | | | | | | |
| Bartlett pear | | | | | | | | | | | | × | × | × | | | |

[1] This table is not intended to indicate the seasonal abundance of host fruits.

TABLE III.—*Data indicating the seasons of the year when inspectors of the clean-culture campaign collected various fruits infested by the Mediterranean fruit fly*[1]—Continued.

| Fruit. | May 5–10. | May 12–17. | May 19–24. | May 26–31. | June 2–7. | June 9–14. | June 16–21. | June 23–28. | June 30–July 5. | July 7–12. | July 14–19. | July 21–26. | July 28–Aug. 2. | Aug. 4–9. | Aug. 11–16. | Aug. 18–23. | Aug. 25–30. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocado | | | | × | | | | | × | × | × | × | × | × | × | × | × |
| Carambola | × | | | | | | | | | | × | × | × | × | × | × | × |
| Chinese orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Chrysophyllum spp | | | | | | | | | | | | | | | × | × | |
| Coffee | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Damson plum | × | × | × | × | | | | | | | | | | | | | |
| Surinam cherry | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Fig | × | × | | × | × | | | | | × | × | × | × | | × | × | |
| Grapefruit | × | × | | | × | | | | | | | | × | | × | × | |
| Guava | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kamani, ball | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kumquat | × | × | | | × | | | | | | | | | × | × | × | × |
| Lime | | | × | | × | × | × | | × | × | | × | × | × | × | × | × |
| Loquat | | | × | × | | | | | | | | | | | | | |
| Mango | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | | |
| Mock orange | × | | × | × | × | × | | × | | × | × | | × | | × | × | × |
| Mountain apple | × | × | × | × | × | | | × | | | | | | | | | |
| Orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Papaya | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Peach | × | × | × | × | × | × | × | × | × | | | × | × | × | × | | |
| Pepper | | | | | | | | | | × | × | | | × | | | |
| Prickly pear | | × | | | | | | × | × | × | × | × | × | × | × | × | × |
| Rose apple | × | × | × | × | × | × | × | × | × | × | × | × | × | | × | × | |
| Star apple | × | × | | × | × | | | | | | | | | | | | |
| Bestill | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Sour sop | × | × | × | | × | × | × | × | × | × | × | | × | × | × | × | × |
| Mandarin | × | × | × | | | | | × | | × | | | × | | × | × | × |
| Lemon | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kamani, winged | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Spanish cherry | | | | | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Bartlett pear | | | | | | | | × | | | | | × | | | | |

| Fruit. | Sept. 1–6. | Sept. 8–13. | Sept. 15–20. | Sept. 22–27. | Sept. 29–Oct. 4. | Oct. 6–11. | Oct. 13–18. | Oct. 20–25. | Oct. 27–Nov. 1. | Nov. 1–9. | Nov. 11–16. | Nov. 18–23. | Nov. 25–30. | Dec. 2–7. | Dec. 9–14. | Dec. 16–21. | Dec. 23–31. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Avocado | × | × | × | × | × | | | × | | | | | | × | × | × | × |
| Carambola | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Chinese orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Chrysophyllum spp | | × | × | | × | | | × | | | | | | | | | |
| Coffee | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Damson plum | | | | | | | | | | | | | | | | | |
| Surinam cherry | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Fig | × | × | | × | | × | | | | × | | × | × | × | × | | × |
| Grapefruit | | | | | × | × | | | × | × | × | | × | × | × | | × |
| Guava | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kamani, ball | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kumquat | | × | × | × | × | × | × | × | × | | | | | × | | | × |
| Lime | | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Loquat | | | | | | | | | | × | × | × | × | × | × | × | × |
| Mango | × | | | | | | | | × | × | × | × | | × | × | × | × |
| Mock orange | × | × | | × | × | × | × | × | × | × | × | × | | × | × | × | × |
| Mountain apple | | | | | | | | | | × | | × | | × | | | × |
| Orange | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Papaya | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Peach | × | | | | × | | | | | × | | | | | | | × |
| Pepper | × | × | × | × | | | | × | × | × | × | × | × | × | | × | × |
| Prickly pear | × | × | × | × | × | × | × | × | | | | | | × | × | × | × |
| Rose apple | | | | × | × | | × | × | | | | | | | | × | |
| Star apple | | | | | | | | | | | | | | | × | | |
| Bestill | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Sour sop | × | × | × | × | × | × | × | × | × | × | | | | | | | |
| Mandarin | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Lemon | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Kamani, winged | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Spanish cherry | × | × | × | × | × | × | × | × | × | × | × | | | | × | × | |
| Bartlett pear | | | | | | | | | | | | | | | | | |

### HOST CONDITIONS IN THE COUNTRY.

While host conditions within the city limits render useless such artificial control measures as can be applied under existing conditions, country host conditions are almost, if not quite, as discouraging. Here the fruit fly has been able to establish itself, often miles from towns, in some one or more of its hosts which have escaped cultivation and have spread over uncultivated and uncultivable areas. Of such hosts, the common guava is the most abundant. It has taken possession of the roadsides, pastures (as shown in fig. 26), vacant town lots, mountain gulches and hillsides, and even crevices on precipices. So easily does the plant grow from seed and so thoroughly distributed are its seeds by cattle, birds, and man,

FIG. 26.—Men cutting down a dense thicket of guava bushes. In such a guava scrub ripening fruits are present throughout the entire year and in them the Mediterranean fruit fly breeds, often far from cultivated fields. (Authors' illustration.)

that it is seldom that in the lowlands, except in very arid areas, a bush can not be found within a stone's throw. In pastures and mountain gulches up to an elevation of at least 1,500 feet, particularly where sheltered from strong winds and well watered, the guavas may become very treelike and form dense thickets. While the guava fruits most heavily during the spring and fall months, the bushes are continuously in bloom and ripen a sufficient number of fruits to support the fruit fly every month in the year.

Second to the guava as a host occurring in the wild uncultivated areas is the prickly-pear cactus. Though the fruits of this plant are not preferred by the fruit fly, they are sufficiently infested in the absence of more favored hosts to serve as food, and, as in the case of the guava, there is almost no time during the year when a few ripe fruits can not be found in any cactus scrub.

Other host fruits, wild or escaped, are not so generally distributed. As a few of the many examples, there may be mentioned a grove of ball kamani trees in an isolated valley on the Island of Molokai, gulches overgrown with the passion vine and the damson plum on the island of Maui, the thickets of winged kamani growing along the windward shores of the island of Oahu, and the wild coffee in the forests of Oahu and Hawaii.

In addition to the wild fruits in country places, the fruit fly finds strongholds in the many, and often isolated, native home sites scattered throughout the coastal region. About these may be growing the mango, rose apple, orange, peach, ball and winged kamanis, etc. The Kona district of Hawaii has large areas containing thousands of acres of coffee under cultivation in which the fruit fly finds food at all seasons of the year, because of the uneven ripening of the crops due to the varying altitudes at which coffee is grown.

### CLEAN CULTURE A FAILURE IN HAWAII.

Clean culture in its broadest sense includes not only the detection, collection, and destruction of all infested fruits, but also the elimination of useless or unnecessary host vegetation. In some one or all of its phases it has been recommended and practiced in every country where the fruit fly is a pest, but in nearly all of these the apparent indifference displayed by the majority of the people, no matter how much they may have lamented their losses, has rendered clean culture inefficient.

The clean-culture campaign instituted by the Hawaiian board of agriculture during the fall of 1911 and continued by the Federal Bureau of Entomology from October, 1912, until April, 1914, was a failure from the very start in that it did not protect fruits from attack. There were minor contributory causes, but the main reason for failure was the insurmountable difficulties placed in the way of success by territorial legislation, adverse host and climatic conditions, and the lack of any commercially grown crop worth protecting. This method of control proved hopeless after the first few months' trial from the standpoint of alleviating the Hawaiian situation, and while the destruction of fruit was encouraged, in the absence of a better plan for lessening the opportunities for spread of the pest to the coast by means of infested fruits carried on board ships sailing from Honolulu, it has since been discontinued.

It is doubtful if any clean-culture campaign against the fruit fly has ever been organized so efficiently or on so large a scale as was that organized by the Hawaiian board to include Honolulu. That this method should prove a failure under Hawaiian conditions is no reflection upon the ability of those directly in charge of the work. The law prohibited inspectors from gathering and destroying the

fruits unless they could first prove to the satisfaction of the property holders that each fruit was infested. This restriction placed upon the activity of the inspectors led to numerous difficulties between inspectors and those opposed to clean culture. This law also prohibited a systematic gathering of all host fruits within a given area, thus necessitating many examinations for the removal, as they ripened, of the fruits of each single tree. As fruits ripen rapidly in the semitropics, it proved a physical impossibility to arrange visits of inspectors frequently enough to prevent infested fruits from falling to the ground.

The data of Tables II and III demonstrate the immense number and diversity of host trees and shrubs in Honolulu and the ease with

FIG. 27.—Ball kamani trees grown for shade and ornament. This tree grows to a large size, and sometimes in dense thickets in the forest. Its fruits ripen at all seasons of the year and are badly infested by the Mediterranean fruit fly. (Authors' illustration.)

which the fruit fly, uncurbed by climatic conditions, finds fruit for egg laying during any day of the year. It is absurd to endeavor to remove all the fruit from many of the huge trees of the islands. There are numerous large trees (figs. 27, 28) beneath which infested fruits may be gathered each week in the year, yet the trees are so tall and brittle that no inspector can remove the fruits before they ripen. One yard in Hilo has 15 host trees from 20 to 50 feet high. To these examples might be added many others in which the removal of fruits is equally impracticable. Often the fruits of the star apple, for instance, ripening in the tops of tall trees do not fall until long after they have shriveled up and until after the many larvæ developing within have matured and dropped from them to the ground. One

acre of guava or of coffee can support the fly throughout the year without the aid of other host fruits and form a center for the reinfestation of surrounding areas. Notwithstanding the fact that the bulk of the ripening and infested fruits can be collected except during the mango season, lasting from May to July, and fruit-fly conditions unquestionably improved from the standpoint of the numerical abundance of adult flies, the important fact remains that the number of fruit flies that succeed in reaching maturity is sufficiently large to infest practically every fruit ripening within the city.

Clean culture can not be made effective under present conditions. The islands are thoroughly overrun with the fruit fly, and this applies

FIG. 28.—The fruits of this tree, the winged kamani, ripening throughout the year, are badly infested by the Mediterranean fruit fly. The nuts of this one tree are enough to supply adult flies for an entire neighborhood. (Authors' illustration.)

quite as much to the guava scrubs in pastures or lava flows and in mountain gulches as within city limits. By far the larger proportion of the host trees and shrubs are grown more for protection from the tropic sun and for their ornamental value than for their fruits. Large numbers of the host fruits are not edible. The destruction of host vegetation is out of the question until it can be proved that some worth-while advantage can be gained. To cut down all host trees in Honolulu at present would mean the removal of a large percentage of her prized vegetation without giving her citizens any adequate compensation.

### VALUE OF ELIMINATING HOST VEGETATION.

In Honolulu many mango and orange trees were either cut down or severely trimmed, but those cut formed too small a percentage of the entire host vegetation to serve a practical purpose. The only places where the elimination of host vegetation yielded favorable results were about banana and pineapple plantations where the work was done in accordance with the regulations of the Federal Horticultural Board. In these instances the destruction of vegetation did not eliminate the adult flies, for these came in from surrounding areas. It did, however, lessen the danger of immature stages becoming attached to the packing material of bananas and pineapples shipped to the mainland.

Should the Mediterranean fruit fly ever become established in California or the Southern States, however, where there is no such wealth of native host fruits and where climatic conditions will prove an important factor in control, the elimination of host vegetation will play a most valuable part in remedial measures. In Algeria the infestation of oranges greatly increased after such crops as peaches and persimmons were grown. These fruits furnished food for the fly during the summer and early fall months, which were for the fly starvation months previous to the cultivation of these crops. Aided by these summer crops, the fruit fly was able to increase greatly, so that when the orange crop began to ripen during the fall and winter months the pest could attack it with increased force. In Bermuda the elimination of a comparatively few host trees, numerically speaking, would mean the elimination of breeding places for considerable areas. The destruction of unnecessary and valueless host trees will not only restrict the breeding ground, but will often so break up the sequence of ripening hosts that many adult flies will die while attempting to bridge the starvation periods when no fruits can be found for egg laying.

### DESTRUCTION OF INFESTED FRUITS AND SPRAYING.

The destruction of infested fruits and spraying are remedial measures that should go hand in hand. In Honolulu they have not given satisfactory results for reasons beyond the control of man, as set forth on pages 24 to 33. Nevertheless, they can be made successful in commercial orchards, if applied with intelligence and persistence throughout a neighborhood. One indifferent neighbor can spoil the work carried on in surrounding orchards. A community of growers must determine in what crop their interests are centered and impartially eliminate nonessential fruits. Then, and, as a rule, not until then, will labor spent on the destruction of infested fruits and

on spraying prove worth while. Sprays are applied to kill the adults; fruits are destroyed to kill the eggs and contained larvæ.

### DESTRUCTION OF INFESTED FRUITS.

Larvæ infesting fruits may be killed by submerging the fruits in water or by burying, boiling, or burning the fruits. The choice of method will depend largely upon the quantity of fruit to be handled and upon local conditions. The surest way to kill all immature stages of the fruit fly is to boil or burn the fruits. Burning the fruits is often expensive and, when trash in compost holes is depended upon to furnish the fuel, the burning operation is likely to be unsatisfactory; for in Honolulu, at least, the amount of fruit to burn is so greatly in excess of the trash that the work is incompletely done. Bringing infested fruits to the boiling point will kill all forms of the fruit fly. Submerging fruits in ordinary cold water for five days will either kill all larvæ and eggs or prevent their further development.

Burial in soil is a satisfactory method, provided the fruit is buried deep enough and afterwards cracks are prevented from developing in the earth above the fruits as the latter decay and settle. It should be remembered that just after transforming from the pupa the adults are so soft that they have the remarkable ability to force their way through incredibly small openings. Hence, a crack in the soil extending down to the fruit, even though it be no wider than the thickness of ordinary blotting paper, is wide enough to permit the adults to reach the surface and so thwart the purpose of fruit burial. Adults can not make their way through 1 foot of well-tamped soil, but because burial or burning is left to subordinates, who may slight the work, boiling or submergence of fruit in water is more highly recommended.

### SPRAYING.

As adult flies can not lay eggs until 4 to 10 days after they emerge from the pupa, anything that will kill them during this period is useful. Such a remedy has been found in poisoned-bait sprays. These are composed of a sweet substance attractive to the flies, a poison, and water. Mally, who first used a poisoned spray in controlling this pest, used a formula containing: Sugar, 3 pounds; arsenate of lead, 4 ounces; water, 5 gallons. This he applied at the rate of 1 to 1½ pints to each 10-year-old peach or nectarine tree. Lounsbury used 6 pounds of brown sugar, 6 ounces of arsenate of lead paste, and 8 gallons of water. Severin used the Mally formula but increased the poison to 5 ounces. Weinland used 3½ ounces of arsenate of lead, 10 pounds of brown sugar, 5 gallons of plantation molasses, and 50 gallons of water. All of these formulas have proved to be efficacious.

Attempts to control the Mediterranean fruit fly under Honolulu conditions were unsuccessful. The number of adults killed was great, yet a sufficient number survived to infest all fruits that ripened. From what is known, however, of the benefits derived from these sprays in other countries, there is no question but that poisoned-bait sprays, when intelligently applied under such commercial conditions as exist in California and Florida, will prove successful. Thus Mally in South Africa states that a "severe outbreak of the pest in a commercial peach orchard was brought to a sudden and practically complete halt, and the fruit maturing later was marked under the guarantee of freedom from maggots," while the infestation among fruits on check trees increased until all fruits became infested. Newman in Western Australia estimates the cost of spraying an acre when one application of one pint of spray per tree is made every 12 to 14 days to be from $1.50 to $2 per fortnight, and states that this sum is a mere bagatelle to the loss of fruit during a similar period over a like area. Both Mally and Newman, working under conditions of less rainfall than obtained at Honolulu, and more like those of California and of fall and winter in Florida, believe that good results will follow the consistent application of poisoned bait sprays, particularly when supplemented by the proper destruction of infested fruits.

Honeybees are not endangered by the application of poisoned-bait sprays.

### COLD-STORAGE TEMPERATURES.

Cold-storage temperatures do not lessen the damage already done fruits by larvæ within them, but they may become of inestimable value in guarding fruits against further attacks while in storage or transit and in freeing them from suspicion as carriers of the fruit fly.

For the details of the effect of cold-storage temperatures upon eggs, larvæ, and pupæ of the Mediterranean fruit fly, application should be made to the Bureau of Entomology for articles already published. Fruits of almost any variety commonly held in storage are held at temperatures varying from 32° to 45° F., with preference shown to a range of 32° to 36° F. It may be said that no immature stages of the Mediterranean fruit fly can survive refrigeration for seven weeks at 40° to 45° F., for three weeks at 33° to 40° F., or for two weeks at 32° to 33° F.

It seems reasonable to conclude that sooner or later the certification of properly refrigerated fruit will be practicable. When an association of fruit growers, or a people, find it financially worth while, there is no reason why they can not operate a central refrigeration plant under the supervision of an official whose reputation shall be sufficient to guarantee all fruits sent out from the plant to be absolutely free from danger as carriers of the fruit fly.

### PROTECTIVE COVERINGS.

The only certain method now known of protecting fruit from fruit-fly attack in Hawaii is to cover them, when still very green, with some type of covering through which the fly can not lay her eggs. In many places ordinary cheesecloth sewed into bags, large enough to be slipped over the tree and tied about the trunk, have been used. These have been tried in Honolulu, but difficulty was experienced in putting the bags on soon enough and in making certain that no adult female flies were inclosed during the process. Considering the cost of material and the real danger of inclosing flies, the impossibility of covering many trees, and the breakage due to winds, this method of protection is not recommended.

The protection of the fruit on individual branches with coverings of cloth or paper is entirely feasible and very popular in Hawaii. Individual fruits inclosed in ordinary paper bags (fig. 29) are well and cheaply protected. Coverings of cheesecloth for separate fruits are not as good as paper, for the fruit fly can lay her eggs through certain coarser-woven kinds after the cloth has become matted against the fruit by rains.

Orange and small mango trees with their fruits inclosed in paper bags are often seen in Honolulu. Though this method of covering each fruit gives protection, it involves much labor and patience, and its practicability can be determined only by the value placed upon the fruit by the owner. So severe, however, is fruit-fly attack in Hawaii that this method, or some one of its many modified forms, must be used if fruits are to be brought to maturity uninfested.

FIG. 29.—Quince fruit protected from fruit-fly attack by a paper bag. The bag is slipped over the fruit while it is still quite green. Although this method of protection is not practical on a large scale, it is used much in Hawaii for the protection of dooryard or experimental fruits. (Original.)

### NATURAL CONTROL OF THE FRUIT FLY.

No striking examples of control by natural agencies were evident in Hawaii previous to the introduction of parasites. Larvæ are killed in large numbers within fruits which are permitted to remain on the

ground exposed to the direct sunlight in summer, but many larvæ escape even from such fruits. An examination of 17 mangoes exposed over sand on shallow trays to the sun for two days in August revealed 17 living and 98 dead well-grown larvæ in the fruit, and 103 that succeeded in safely leaving the fruit to form pupæ in the sand beneath. The small brown ant,[1] so common about the lowlands of Hawaii, unquestionably is a factor in natural control. It is frequently found swarming over and in fallen fruits and kills many larvæ as they leave the fruits to pupate. Ants were observed to remove from a fallen ball kamani nut 86 medium-sized larvæ during a 40-minute period, but they failed to reach 34 other larvæ in a firmer portion of the fruit.

No natural checks upon fruit-fly increase in Hawaii, aside from introduced parasites, are of practical value; but in many other lands climatic checks are unquestionably of great value, and, as in many places in Spain, for instance, are the only checks that make fruit production possible without the use of remedial measures.

### CLIMATIC CHECKS.

Observations made in various countries indicate that the Mediterranean fruit fly will not be a serious pest when the monthly mean temperature falls to or below 50° F. for from three to four consecutive months during the year. In Hawaii the climate is not cold enough throughout the fruit-growing regions to act as a serious check on fruit-fly increase. Development progresses most rapidly after the Hawaiian means reach 75° to 79° F. At a mean of 68° F. development requires about twice the time. A temperature of 58° to 62° F. may increase the period of development to three to four times the normal period for the warmest weather. Larval development in apples stored outdoors at temperatures ranging from 31° to 64° F. (mean, about 51° F.) was slow and was attended by no unusual mortality. No development occurred at 26° to 70° F. (mean, 48° F.), and nearly all larvæ were dead at the end of six weeks. Very few fruit flies can develop at 49° to 50° F., and none at temperatures below this point. Complete mortality will follow continued exposure to temperatures below 50° F. An exposure for two to three weeks at 32° F. will kill all stages of the fruit fly, but an exposure to this low temperature for four days has practically no effect upon the fly. Sixty-two of 248 larvæ survived an exposure for five days to 21° to 28° F. These facts indicate that the Mediterranean fruit fly is a very hardy and persistent enemy in spite of the quickness with which it responds to checks upon its development resulting from the low temperatures ordinarily experienced in semitropical countries.

[1] *Pheidole megacephala* Fab.

PARASITES.

The very climatic and host conditions that have made the Mediterranean fruit fly an unusually serious pest in Hawaii and that, with crop conditions as they are, have made artificial methods of control impracticable, have been most favorable for an attempt at control by means of parasites. An abundance of the fruit fly upon which to feed and a climate permitting increase each month in the year have made conditions ideal. The search for and discovery of parasites, and their introduction and establishment where previously there had been none, has been one of the entomological romances of the present time. The parasites now at work killing the fruit fly in Hawaii have been introduced by the Hawaiian Board of Agriculture and Forestry as a result of the Silvestri and the Fullaway-Bridwell expeditions to Africa.

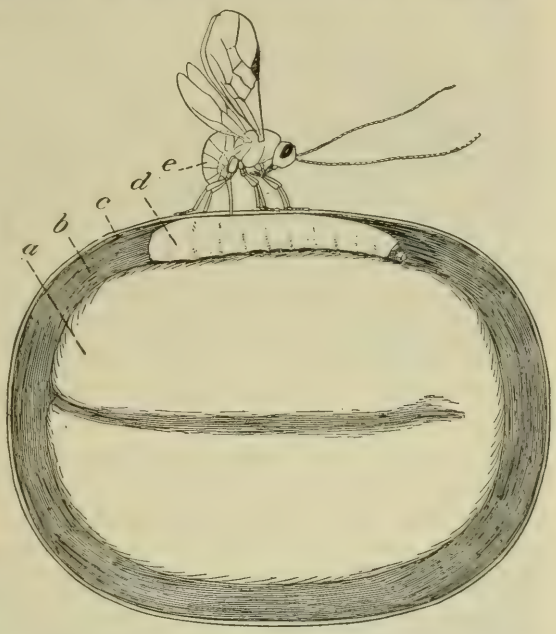


FIG. 30.—Diagrammatic drawing of a cross section of a coffee cherry to illustrate comparative ease with which the South African parasite can lay eggs in the fruit-fly larva: *a*, Coffee bean; *b*, pulp destroyed by maggot; *c*, skin of cherry; *d*, maggot of fruit fly; *e*, parasite forcing its stinger through skin of cherry into maggot. (Original.)

These two expeditions resulted in the establishment in the islands between May, 1913, and October, 1914, of four promising parasites: one from South Africa,[1] one from eastern Australia,[2] and two from Nigeria,[3] West Africa. Of these, only one, the South African Opius, was discovered as a parasite of the Mediterranean fruit fly. The three others were found parasitizing other fruit flies, and they have adapted themselves in Hawaii to the Mediterranean fruit fly. None of them, however, has been known to attack the melon fly in the gardens in Hawaii. Large numbers of all the parasites have been reared and have been liberated in all parts of the islands, until to-day they are well able to care for themselves. They have multiplied with remarkable rapidity and have unquestionably reduced the numerical

[1] *Opius humilis* Silv. [2] *Diachasma tryoni* Cam. [3] *D. fullawayi* Silv. and *Tetrastichus giffardianus* Silv.

abundance of the fruit fly. To-day no batch of infested fruit can be collected from which fruit-fly parasites can not be reared.

Only a beginning has been made in determining the effectiveness of parasites as a control factor against the fruit fly in Hawaii. The rapidity of establishment and the increase of the parasites have been very gratifying, yet the data already published recording the percentages of parasitism during the years 1914, 1915, and 1916 indicate that while parasitism in thin-meated fruits, such as coffee (see (fig. 30), may be consistently very high, in thicker fruits, like the orange, it is consistently very low. Thus the parasitism among larvæ developing in coffee may range between 90 and 100 per cent, while that among larvæ of the Chinese orange is more likely to range from almost nothing to 30 per cent. High parasitism among larvæ in such fruits as coffee is due to the fact that the larvæ are within reach of the parasite. On the other hand, the larvæ within such fruits as the orange may feed about the seeds and therefore remain safe from attack so long as they stay at the core, and are subject to attacks only when they come to the surface of the fruit.

Since adult fruit flies can live many months and lay eggs quite regularly, they have been able, with the aid of the unprecedented variety and abundance of host fruits in Hawaii, thus far to keep such an ascendancy over their parasites that they cause the infestation of practically all fruits ripening. It would appear that unless effective pupal and egg parasites are introduced, or more care is given to the elimination of host fruits which more thoroughly protect the larvæ from parasite attack, or to the planting of fruits which make possible the reproduction of large numbers of parasites, little practical value will result from the work of the parasites from the standpoint of rendering host fruits free from attack.

Though it seems evident that the favored host fruits will always be well infested if present cultural conditions continue, it is hoped that the efficiency of the parasites may be sufficiently enhanced to free from attack such fruits as the avocado and the better varieties of mangoes. In Kona, Hawaii, where the percentage of parasitism in coffee cherries (see fig. 30) has been phenomenally high for three years, it has not been high enough to free more than an occasional cherry from attack. The control exerted by parasites has, however, effected a benefit to coffee growers which probably already has repaid the Territory of Hawaii for all money expended in the introduction of parasites.

The general effectiveness of control by parasites can be increased best by the discovery and introduction of a good egg parasite.

## QUARANTINE MEASURES TO PREVENT INTRODUCTION.

To prevent the Mediterranean fruit fly from becoming established in the mainland of the United States, the Federal Horticultural Board has promulgated Quarantine No. 13, which provides that its agents,

FIG. 31.—Chinese laborers inspecting bananas. Each bunch of bananas exported from Hawaii to California is inspected for bruised, cracked, or suspicious looking fruits. (Original.)

both in Hawaii and at the mainland ports of entry, shall have strict supervision over the movements of all fruits permitted entry to the mainland from Hawaii. Quarantine No. 13 makes it unlawful for a

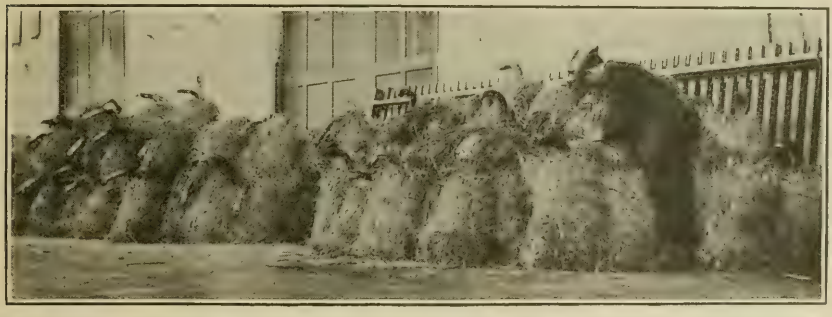

FIG. 32.—Inspecting bananas as they are unloaded on the docks at San Francisco: Inspector making certain that each bunch bears an inspection tag and has been wrapped in material permitted by law. (Photo by Maskew.)

person to ship or carry any fruit from the Hawaiian Islands except ordinary eating bananas, pineapples, taro, and coconuts, and these will not be passed by inspectors at ports of entry, such as San Francisco, Los Angeles, or Seattle, unless they have been inspected by the

Federal agents in Hawaii and bear a Federal certificate of inspection. (Fig. 31.)

In Hawaii every precaution is taken to have bananas and pineapples grown under conditions that will prevent spread of the fruit fly. Plantations, packing sheds, and packing materials are inspected sufficiently often to insure their being in keeping with the regulations of the Federal Board. No fruit can be lawfully accepted for transportation to the mainland by any transporting company in Hawaii until it has been inspected and passed and permits for its acceptance have been issued to the transporting company by agents of the Board. Furthermore, no fruit can be lawfully removed from ships at ports of entry at the mainland unless the permit issued the transporting company in Hawaii is found attached to the bill of lading by the

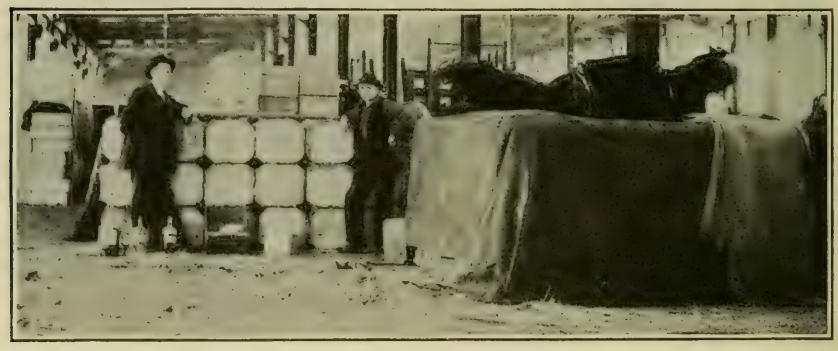

FIG. 33.—Pineapples never breed fruit flies in Hawaii. To be doubly certain that the packing material contains no fruit-fly pupæ, all crates of pineapples unloaded on the docks at San Francisco are fumigated with gas after tarpaulins have been thrown over the crates to prevent the gas from escaping. (Photo by Maskew.)

Federal agent, and unless each package or crate of fruit bears the inspection tag above referred to. (Figs. 32 and 33.)

Passengers and ships are permitted to take on board in Hawaii fruits of all descriptions for consumption while en route to the coast. All contraband fruits, however, must be eaten or destroyed before the ship comes within the 3-mile limit of the mainland. Otherwise the transporting company, or the individual passenger, whichever is the offender, is subject to fine or imprisonment, or both.

## SUMMARY.

The Mediterranean fruit fly has become so thoroughly entrenched in Hawaii as a result of favorable climatic and host conditions that artificial remedial measures for its control are not practicable. Introduced parasites have multiplied wonderfully well and already have proved of practical value in safeguarding the coffee crop from losses due to fruit-fly attack. Though it is certain that the parasites can

never exterminate the fruit fly or cause the raising of the quarantine against Hawaiian fruits, much ultimate good is expected of them. It is hoped that by lessening the abundance of the fruit fly many fruits that now become badly infested before they are ripe enough to eat may be able to mature uninfested to a point where they will be useful to man. At present almost all edible fruits in Hawaii, and many ornamentals, making a total of 72 kinds of fruit, are subject to attack.

Judging from the past history of the Mediterranean fruit fly, only the vigilance of quarantine officials and the hearty cooperation of travelers will prevent its establishment in California and the Gulf States. Every barrier possible has been erected by State and Federal quarantines, so that there is now little danger of the pest gaining entry through the medium of commercial shipments of fresh fruits. But quarantine officials have found the pest in fruit concealed by tourists and in mail and express packages sent from infested countries by uninformed persons, and it is by such avenues that the pest is most likely to be introduced. These avenues, also, are the most difficult of detection, and their closing is dependent mainly upon educational campaigns to convince the public of the necessity of quarantine measures, and upon the unselfishness and personal honesty of travelers. At present only bananas, pineapples, taro, coconuts, and certain other vegetable products not subject to attack, are permitted entry from Hawaii, and these only after the regulations of the Federal Horticultural Board have been fulfilled.

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